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CONTROL OF EMISSIONS FROM LIGHT PISTON-ENGINE AIRCRAFT

W. F. Datwyler, et al

Bendix Research Laboratories

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Office of Air and Water Programs
Mobile Source Air Pollution Control Program
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FOREWORD

This is the final report on an investigation of the control of emissions from light piston-engine aircraft conducted at the Bendix Research Laboratories for the Environmental Protection Agency under Contract No. 68-04-0045.

The work was administered under the direction of the Emission Characterization and Control Development Branch, Mobile Source Air Pollution Control Program, Office of Air and Water Programs, at Ann Arbor, Michigan. Project officers for initial through final phases of the program were Messrs. Barry D. McNutt, Charles Gray, Jr., and William H. Houtman.

Work was conducted in the Vehicle Controls Department of the Bendix Research Laboratories, Southfield, Michigan. Project supervisors for the initial and final phases of the contract were Messrs. A. Blatter and W. F. Datwyler, respectively; Mr. S. T. Hassan was Responsible Engineer throughout the contract.

The significant technical contributions to this effort by Messrs. McNutt, Gray and Houtman of the Environmental Protection Agency are acknowledged.

ABSTRACT

This final report was prepared by the Bendix Research Laboratories of The Bendix Corporation for the Environmental Protection Agency, Office of Air and Water Programs, under Contract Number 68-04-0045. Work was conducted during the period July 1971 through March 1973. The objective of the work described in this report was to help establish information bearing on the technical and economic feasibility of controlling emissions from light piston-engine aircraft. The study was primarily of an experimental nature directed at observing and evaluating the results of applying existing automotive emission control techniques to aircraft piston engines. Attention was restricted to the emissions of major importance in spark-ignition piston-engine operation, i.e., unburned hydrocarbons, carbon monoxide, and oxides of nitrogen. Control techniques considered were those primarily used to reduce hydrocarbons and carbon monoxide, since the rich mixtures normally used in aircraft operation inherently lead to low levels of oxides of nitrogen. The general program approach was to select two typical engine configurations, design and implement selected emission control provisions, establish baseline emissions outputs for the standard engines, and determine the effect of the various emission control techniques and systems relative to the baseline values.

A Continental 0-200 carbureted engine and a Lycoming IO-540 fuel-injected engine were selected for evaluation. Emissions control techniques and systems selected for evaluation were (1) variations of air-fuel ratio and ignition timing, (2) exhaust treatment by air injection, thermal reaction, and catalytic conversion, and (3) return of crankcase gases to the intake manifold, commonly termed "positive crankcase ventilation", or PCV. Air-fuel ratio and ignition timing were varied using existing mixture control and magneto setting provisions. Exhaust systems were modified as required to incorporate air injectors, thermal reactors, and catalytic convertors. Thermal reactors were specially designed and fabricated since no existing reactors were available. Commercially available catalytic convertors were purchased and used. Tests were conducted on an engine dynamometer with measurement of all pertinent engine variables and exhaust emission components.

The report describes the control approaches selected and tests conducted. Results are presented and discussed. Pertinent data are included for reference.

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SECTION 1

INTRODUCTION

This final report was prepared by the Bendix Research Laboratories of The Bendix Corporation for the Environmental Protection Agency, Office of Air and Water Programs, under Contract Number 68-04-0045. Work was conducted during the period July 1971 through March 1973.

1.1 OBJECTIVE AND SCOPE

The objective of this effort was to help establish information bearing on the technical and economic feasibility of controlling emissions from light piston-engine aircraft.

The study was primarily of an experimental nature directed at observing and evaluating the results of applying existing automotive emission control techniques to aircraft piston engines.

Attention was restricted to the emissions of major importance in spark-ignition piston engine operation, ie., unburned hydrocarbons, carbon monoxide, and oxides of nitrogen. Control techniques considered were those primarily used to reduce hydrocarbons and carbon monoxide, since the rich mixtures normally used in aircraft operation inherently lead to low levels of oxides of nitrogen.

The effort was divided into three task areas:

Technique Survey and Selection - A survey of available automotive-type emission control techniques, consideration of the special light-aircraft problem, and selection of hardware and control techniques for experimental evaluation.

Experimental Implementation and Evaluation - Implementation (design and fabrication, or procurement where possible) of experimental emission control methods and their test and evaluation on two representative aircraft engine models.

Preliminary Feasibility Evaluation - A general evaluation of the light piston-engine aircraft emission control problem, incorporating information from the survey, hardware implementation, and test evaluation efforts.

1.2 PROGRAM APPROACH

The general program approach was to select two typical engine configurations, design and implement selected emission control provisions, establish baseline emissions outputs for the standard engines, and determine the effect of the various emission control techniques and systems relative to the baselines values.

The Continental 0-200 carbureted engine and Lycoming IO-540 fuel injected engine were selected for evaluation as high-utilization configurations representative of a broad spectrum of light aircraft use. The Continental 0-200 is rated at 100 HP and powers the Cessna 150, widely used as a two-passenger training aircraft. The Lycoming IO-540 is rated at 260 HP and is used in such aircraft as the Piper PA-24 four-passenger Comanche.

Emission control techniques and systems selected for evaluation were (1) variation of air-fuel ratio and ignition timing, (2) exhaust treatment by air injection, thermal reaction, and catalytic conversion, and (3) return of crankcase gases to the intake manifold, commonly termed "positive crankcase ventilation" or PCV.

Air-fuel ratio and ignition timing were varied using existing mixture control and magneto setting provisions. Exhaust systems were modified as required to incorporate air injectors, thermal reactors, and catalytic convertors. Thermal reactors were specially designed and fabricated since no existing reactors were available. Commercially available oxidizing catalytic convertors were purchased and used. A pair of air pumps of a type widely used for secondary air in automotive applications were added to the Continental 0-200 and belt-driven from the crankshaft. An aircraft turbocharger of sufficient capacity to provide the maximum secondary air required by the test matrix was incorporated in the Lycoming IO-540 exhaust system. Control of crankcase gas was achieved for each engine by returning the crankcase gas to an injector plate added downstream of the throttle body with a manually adjusted valve to control the crankcase gas flow rate.

Designs for secondary air injection, thermal reaction, and catalytic conversion systems were such to provide preliminary information on control performance as well as on practical implementation. No attempt was made to implement provisions for automatic air-fuel ratio, ignition timing, or PCV control.

Tests were conducted with the engines installed on an engine dynamometer, with load power points (speed and torque combinations) selected to represent the five modes of the Proposed Federal LTO (Landing-Takeoff) cycle.[1] Cooling air was provided by a blower which forced air over the engine in a manner similar to that used by the engine manufacturers.

Induction air and fuel flows were measured to establish fuel consumption and air-fuel ratio (A/F), and A/F calculations were subsequently verified by analysis of exhaust gases using a carbon balance method. Oil, cylinder head, and exhaust gas temperatures were observed to monitor engine status.

In order to facilitate the measurement of exhaust gas emissions, the Continental 0-200 exhaust manifolds were interconnected at a "T" approximately two feet downstream of the normal individual exhaust system outlets and were vented to atmosphere through a single common pipe into the test cell scavenge system. Exhaust gas was sampled by a probe located in the common path downstream of the "T". The exhaust manifolds on the Lycoming IO-540 engine connect into a common heat muff, and exhaust gas composition was measured at the outlet pipe from the heat muff.

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[1] Paragraph 87.102, page 26497. (References are listed in Section 5).

Gas analyzers were used to measure total hydrocarbons (THC) carbon monoxide (CO), and oxides of nitrogen (NO_x) as required to evaluate emissions and control performance. Carbon dioxide (CO_2) and oxygen (O_2) were also measured as crosscheck indicators of engine and system behavior and for use in the carbon balance analysis of air-fuel ratio.

1.3 SUMMARY OF TEST RESULTS

The following tests were conducted on the respective engines and systems.

Continental 0-200 Engine - Laboratory test at five power settings of the effect on performance and emissions over a suitable matrix of:

- Variations in Engine Variables (A/F and Ignition Timing)
- Positive Crankcase Ventilation
- Exhaust Treatment Systems
  - Secondary Air Injection
  - Thermal Reaction
  - Catalytic Conversion

Lycoming IO-540 Engine - Laboratory test at four power settings of the effect on performance and emissions over a suitable matrix of:

- Variations in Engine Variables (A/F and Ignition Timing)
- Positive Crankcase Ventilation
- Exhaust Treatment Systems
  - Preliminary tests using a turbocharger as a secondary air pump

Effect of Engine Variables

The effects of engine variables (air-fuel ratio and ignition timing) on exhaust emissions, temperatures, and brake specific fuel consumption (BSFC) are presented in Sections 3.2.1 and 3.3.1 for the Continental 0-200 and Lycoming IO-540, respectively.

The effects of varying air-fuel ratio follow the classical pattern in that THC and CO decrease and NO_x increases as A/F is increased toward stoichiometric. Cylinder head temperatures (CHT) and exhaust gas temperatures (EGT) increase, and BSFC decreases for increased A/F in the range tested (10 - 13).

Retarding the ignition timing by 5-degree and 10-degree increments from the factory settings is shown to have negligible useful effect on reducing THC and CO. The reduction in NO_x observed for the same conditions is also not significant.

Retarding the timing results is increased EGT and some slight reduction in CHT for the range tested. BSFC tends to increase because of the less effective combustion within the cylinders.

Effect of Exhaust Treatment

Detailed evaluation of exhaust treatment approaches was limited to the Continental 0-200 engine. Results of that evaluation are presented in Section 3.2.3 with all significant data and computed values tabulated in Appendix B.

The catalytic convertor approach provides the best overall performance at all modes; even at taxi/idle powers where exhaust gas temperature is inadequate for effective simple secondary air or thermal reactor operation. The secondary air and thermal reactor approaches did not "light off" (i.e., initiate significant combustion) at taxi/idle modes with standard ignition timing.

An apparent slight superiority of the secondary air approach over the thermal reactor approach is felt to be a consequence of the longer-than-standard exhaust configuration used to allow single-point measurement of exhaust gas emissions. A more realistic secondary air configuration using conventional exhaust system lengths may have significantly less effectiveness because the exhaust would be vented to atmosphere before substantial combustion could occur.

Evaluation of secondary air injection using a turbocharger on the Lycoming IO-540 engine was limited to preliminary runs because of controllability problems experienced with the test configuration implemented.

Effect of PCV

The return of crankcase gas to the intake manifold to eliminate the release of crankcase gas to the atmosphere was found to have a relatively small effect on engine performance and exhaust stack emissions. Crankcase flow is only about 1-2 percent of the induction air flow and tends to be rich in hydrocarbons. Other studies[2] indicate that up to 25 percent of the total engine hydrocarbon emissions are composed of the vented crankcase gases. The potential icing problem inherent in crankcase gas control systems was graphically demonstrated during the tests in that the line from the crankcase to the intake manifold had to be electrically heated to prevent significant condensation in that line and flow meter even in the +100°F ambient temperature test area.

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[2] p. 7-44

1.4 COMMENTS AND CONCLUSIONS

All experimental evaluations were conducted on a comparative rather than an absolute basis. That is, the effect of PCV and the various exhaust treatment systems were tested for performance relative to a non-modified engine, over a general matrix of conditions.

The proposed federal standards for emissions from aircraft engines were issued December 1972,[1] essentially at the end of the experimental study effort. With the publication of the proposed standards it became possible to compare the effect of various emission control approaches to the standards, and such a comparison is made in Section 4.2 of this report.

A set of air-fuel ratios was selected for the various modes in the range of 10 to 11.5 depending upon the mode, as shown in Section 4. Using those assumed values for air-fuel ratio, nominal LTO cycle emissions for the two engines were calculated from emissions data measured in the study. Recommended factory ignition timings of 28 degrees BTDC and 25 degrees BTDC were used for the 0-200 and IO-540 baseline conditions, respectively. Mass emissions derived for the two engines are shown in Tables 4-3 and 4-4.

As tested, and for the air-fuel ratios assumed, the THC values are close to the proposed standard values, NO_x is below by an approximate factor of ten, and CO is greater by a factor of two. A leaner set of air-fuel ratios would tend to reduce CO and THC and increase NO_x.

The emissions can be modified by selectively varying air-fuel ratio or by the application of exhaust treatment systems. To give a general indication of conditions which result in emissions levels which meet the proposed standard levels, several air-fuel ratio combinations were derived which give suitably reduced emissions. An example was also derived for each of the three exhaust treatment approaches. For simplicity, ignition timing was left at the factory settings for all cases calculated.

The assumed conditions and the resultant emissions are presented in Table 4-5.

The calculations indicate that various combinations of air-fuel ratio and mode exist which result in emissions values at or below the proposed standards. For example, if all modes are uniformly leaned to achieve the required emissions reductions, air-fuel ratios in the order of 13.5 are required. If the lower power modes (i.e., taxi and approach) are leaned to stoichiometric, the takeoff and climbout modes can be enriched for cooling purposes.

Each of the exhaust treatment approaches can reduce the emissions as required, with the 100 percent secondary air condition and for the average 11.5:1 air-fuel ratio assumed.

It should be noted that, for the examples cited, emissions (in particular CO) were only required to be no greater than the proposed standard value. Any factor applied to new engines to allow for manufacturing tolerances and aging effects between overhauls would, of course, increase the air-fuel ratios and secondary air numbers shown in the examples.

Control of air-fuel ratio is a direct method for controlling emissions. Increased air-fuel ratio also generally results in greater fuel economy and in some cases would require only relatively simple modifications to existing fuel management systems. Since fuel injection systems already incorporate means for scheduling mixture against throttle setting, only minor changes in the existing basic configuration could provide a form of emission control for those models. For simple carbureted engines, air-fuel ratio control might require more mechanical refinement to ensure that the desired air-fuel ratio is maintained over the operational range.

If cylinder head temperature or other considerations do not allow simple revisions of air-fuel ratio to adequately achieve the requisite emission levels for a given engine/airframe system, an additional step short of exhaust treatment would be to improve air-fuel preparation and distribution for more precise control of the mixture in the individual cylinders. This would allow increased average leanness with minimum increased individual cylinder and exhaust port temperatures.

Considerable effort is currently being made to reduce exhaust emissions in automobiles by improving air-fuel mixture preparation and combustion, as with stratified charge techniques and various fuel preparation devices. Such technology might well be available and useable for aircraft engines produced in 1979.

As indicated by data obtained on the Continental 0-200 engine with simple air injection, thermal reactors or catalytic convertors, it was possible to reduce THC and CO to the proposed levels or less with each of the experimental exhaust treatment systems. The three exhaust treatment approaches vary in effectiveness and in cost of implementation. Simple secondary air injection into a nominally standard exhaust system is the simplest and potentially the least expensive exhaust treatment system. A thermal reactor is, in effect, a specialized exhaust manifold but would cost and weigh more than a standard exhaust manifold. At current state of the art and utilization, catalytic convertors would be more expensive than thermal reactors and are more subject to heat damage and pollution by leaded fuel.

All three require a source of air for operation. In performance, the secondary air and thermal reactor approaches are limited to use at power levels where exhaust gas temperature is in the order of 1100 to 1200°F. At lower temperatures combustion will not start, even though air is injected and mixed with the exhaust gas, and no reduction in exhaust emissions will result. For the Continental 0-200 engine as tested, this ruled out the use of simple secondary air injection for the idle/taxi modes and, in fact, required spark retardation for functionality of the thermal reactor at those modes. Once exhaust gas temperature has reached the required level for combustion, a well-designed thermal reactor ordinarily would provide greater emission reduction than simple secondary air injection.

By virtue of its physical properties, a catalytic convertor offers the advantages of starting and maintaining combustion at exhaust gas temperatures experienced at idle/taxi conditions and achieving generally more effective conversion of THC and CO.

None of the three approaches have a material effect on the amount of NO_x generated by the engine.

Considering the limited scope of this investigation, it would not be appropriate to draw broad general conclusions as to the feasibility of applying one type of control or another to all light-aircraft piston engines. However, the results of the study do provide an example of emission control technology as applied to two representative engines.

Although only two engines were tested, they were selected to span a large part of the light-aircraft, piston-engine power spectrum and include both carbureted and injected fuel control systems.

Tests were conducted on a dynamometer which allowed good control of conditions and accurate measurement. Since the original emphasis of the test program was to obtain comparative data, such a laboratory approach should not be a substitute for subsequent investigation of flightworthy systems, including flight test.

On the basis of this study, it would appear that further investigation of piston engine emissions should initially emphasize fuel and air management over exhaust treatment as the most promising approach to the control of emissions from light piston-engine aircraft.

SECTION 2

SELECTION AND IMPLEMENTATION OF EMISSION CONTROL APPROACHES

2.1 GENERAL APPROACH

The objectives of the initial phase of the program were to:

(1) Determine the state of the art of existing automotive emission control techniques which may be suitable for aircraft piston engines.

(2) Conceive implementation methods and techniques for the various emission control systems.

(3) Estimate the consequences of applying those systems to general aviation piston-engine aircraft.

(4) Select the most suitable system for subsequent detailed investigation.

To accomplish these objectives the following activities were performed.

Literature Survey

A variety of papers, reports, manuals, books and other pertinent technical publications were surveyed and reviewed. Areas covered specifically included automotive emissions and control technology, I.C. engine performance and combustion technology, aircraft operations and piston engine characteristics, and aircraft emissions studies as sponsored by EPA up to that time. A bibliography is included at the end of this report.

Contacts with Technical Personnel and Organizations

Many manufacturers were contacted for technical information and operating limitations of the various emission control hardware and power plants. The interpretation and application of such information to this project remained the responsibility of EPA and the contractor.

Airframe Manufacturers - Piper Aircraft Corporation (Lock Haven, Pennsylvania) was visited and telephone contacts were held with Cessna Aircraft (Wichita, Kansas) for pertinent technical background information on the Piper PA-24 and Cessna 150 aircraft.

Aircraft Engine Manufacturers - Continental Motors Corporation (Muskegon, Michigan) and AVCO-Lycoming Division (Williamsport, Pennsylvania) were visited early in the program to establish personnel contacts, observe test facilities, and discuss the general impact of emission control systems on aircraft engine performance. Contacts were maintained throughout the program for miscellaneous technical inputs relative to the operation of the engines during the test phase.

Catalyst Manufacturers - American Cyanamid Company, Universal Oil Products, W. R. Grace-Davison Division, Arvin Industries, and Englehard Corporation were contacted for technical information and availability data on suitable catalytic convertors. Englehard Corporation subsequently was visited to discuss the design and procurement of catalytic convertors for the Continental and Lycoming engines to be tested.

Secondary-Air Device Manufacturers - Telephone and mail contacts were made with Rajay Industries, Inc., and Piper Aircraft Corporation regarding the procurement, installation and performance of aircraft turbochargers. GM-Saginaw Steering Division and Bendix Brake & Steering Division were contacted regarding conventional automotive secondary air sources.

Thermal Reactor Developers - Dupont Petroleum Chemical Division was contacted for various technical information and background relating to the use and design of thermal reactors. No source for procuring suitable existing thermal reactors was found since the aircraft requirements are considerably different from automotive.

Government Agencies - The FAA Flight Standards District Office was contacted for background relative to flight tests of emission-control-equipped engines. Potential operational site requirements were also discussed.

Fuel Sources - The procurement of aviation fuel in standard grades (80/87) and (100/130) and the possibilities of obtaining low or unleaded fuel for the test program were discussed with Shell, American Standard and Texaco.

Special Studies and Reviews

Several special analyses and preliminary design studies were conducted for guidance in the selection and subsequent implementation and test phases. These included aircraft performance, secondary air requirements and pump sizing analyses, and propeller load tests. Work in process at the Bendix Research Laboratories under EPA Contract EHS 70-122, "Control of NO_x Emission from Mobile Sources," was also monitored for suitable specialized inputs.[3]

Information thus derived was used as background in the evaluation and final selection of engine models, emission control techniques and test approach and matrices in the program.

2.2 AIRCRAFT PISTON ENGINE EMISSIONS

Typical light aircraft and automotive piston engines are basically Otto-cycle engines and therefore have quite similar combustion and performance characteristics. They exhibit the same general output characteristics (power, emissions, etc.) for changes in inputs such as air flow, air-fuel ratio, ignition timing, load, speed, etc. Exhaust emissions and specific fuel consumption for both engine types are strongly influenced by air-fuel ratio, as shown in Figure 2-1. Given these facts, a major portion of automotive emission control technology is pertinent to the control of emissions from light piston-engine aircraft.

Different detailed considerations exist, however, which require that aircraft emission controls be analyzed and treated within the special constraints of aircraft usage. Factors bearing on cost, weight, reliability, safety and maintainability are traded off differently in the automotive and aircraft industries.

Two functional differences between the two types of engines relate to the number of engine input controls under direct control of the operator and the use of fixed ignition timing (except for starting) in aircraft as compared to variable ignition timing used in automotive engines. On an automotive engine the operator generally has direct control

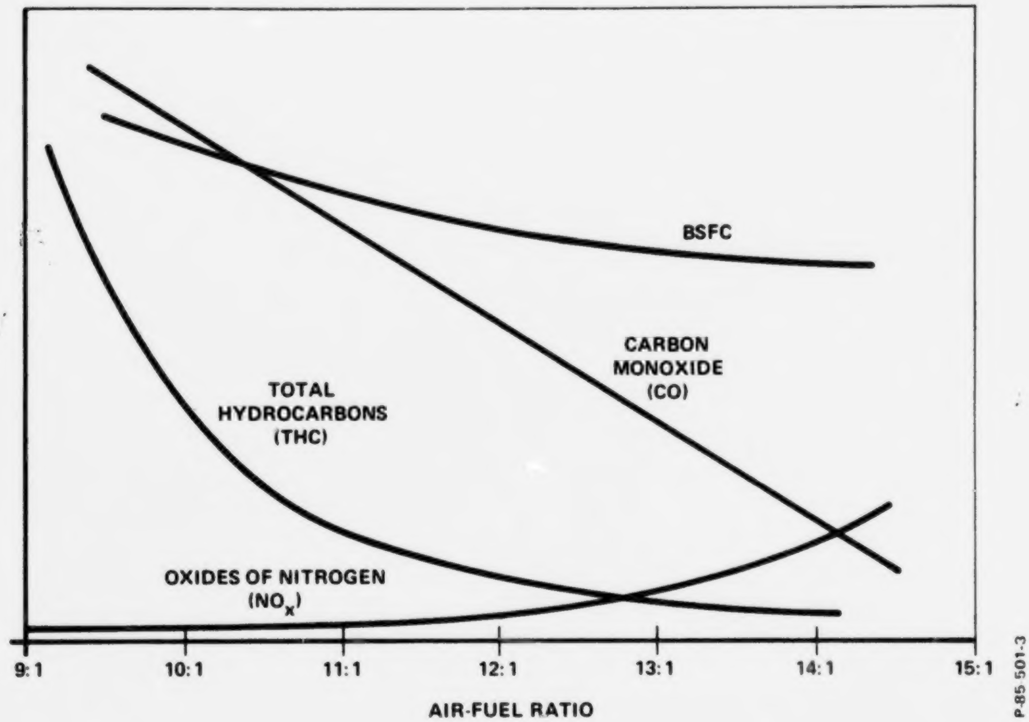

Figure 2-1 - Effect of A/F on Piston-Engine Emissions and BSFC[4]

only over the engine throttle, whereas in an aircraft the operator has direct control over the throttle, inlet air temperature, and air-fuel ratio (mixture).

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[4] Based on Figure 11, p. 64.

The major difference between aircraft and automotive engines in terms of direct effect on emissions and their control arises because aircraft engines are air cooled and, as currently designed and rated, depend significantly upon rich air-fuel mixtures to limit engine temperature to specified levels. Although ratios can range widely within a given sample of engines in the field, piston engines for light aircraft generally operate at air-fuel ratios from 10:1 to 12:0 for operations within the landing-takeoff cycle. Automotive engines are routinely operated at air-fuel ratios in the range of 13:1 to 16:1, except for transient conditions requiring special enrichment (e.g., startup, acceleration, and at high speeds).

For an aircraft without an altitude-compensated fuel management system (i.e., most general aviation aircraft), the rich mixture used for takeoff and climb becomes even more rich as altitude increases because of the reduced density of induction air. Even though engine mixture is normally leaned by the pilot for economical cruise conditions, engine operation on the ground and near the airport is currently conducted in a rich condition relative to the automobile engine.

Considering the rise of hydrocarbons (HC) and carbon monoxide (CO) below air-fuel ratios of approximately 15:1 (Figure 2-1), exhaust emissions from aircraft in the airport area are characteristically rich in HC and CO. They are, however, low in oxides of nitrogen (NO_x) so that, with existing proposed emission standards, the aircraft emission control problem is primarily one of reducing the carbon monoxide and hydrocarbon levels for those flight modes defined by the LTO (Landing-Take Off) cycle without increasing the NO_x to an unacceptable level.

2.3 SELECTION OF CONTROL TECHNIQUES

In recent years the automobile industry has been intensively studying methods to reduce automotive exhaust emissions of hydrocarbons, carbon monoxide and NO_x. The various control methods or techniques can be grouped into three categories.

(1) Those varying engine design and operating parameters such as compression ratio, ignition timing, valve overlap, combustion chamber shape, etc.

(2) Those employing exhaust treatment devices such as secondary air, thermal reactors, catalytic convertors and various combinations of these devices.

(3) Those employing induction system devices such as heated inlet air, various fuel atomization schemes, exhaust gas recirculation, inlet manifold changes for better distribution and more exact control of the air-fuel ratio for various operating modes.

A review of the known automotive emission control techniques was performed. From all of the various possibilities, certain systems were selected and recommended for experimental evaluation. Within the constraint that no systems which required engine modifications were to be considered, the following emission control systems were selected:

(1) Variation of air-fuel ratio

(2) Retardation of ignition timing

(3) Secondary air injection into the exhaust manifolds

(4) Thermal reactors (with secondary air)

(5) Catalytic convertors (with secondary air)

(6) Positive crankcase ventilation

Positive crankcase ventilation (PCV) was included as a candidate control because of the contribution of crankcase flow to engine hydrocarbon emissions.

Exhaust treatment system concepts simultaneously employing both thermal reactors and catalytic convertors were rejected out of hand as not being suitable on the basis of size and weight.

Note that all exhaust treatment approaches for THC and CO require additional air. Contrary to automotive practice, aircraft engines are normally operated at air-fuel ratios much richer than stoichiometric, resulting in essentially no oxygen in the exhaust gas. Thus, additional oxygen (air) must be provided to facilitate the combustion process in the exhaust system.

2.4 IMPLEMENTATION OF TEST CONFIGURATIONS

2.4.1 Engine Variables

The only parameters which could be varied on the engines were the air-fuel ratio and the ignition timing. The aircraft engines both had normal mixture control devices which readily permitted the air-fuel ratio supplied to the engine to be controlled. The mixture controls provide air-fuel ratio control from "full rich" to complete fuel cutoff. Thus, air-fuel ratio control for the test program was easily accomplished.

The aircraft engines tested both use fixed spark timing. No automatic spark variation with speed or load is provided. Timing variations for test purposes were accomplished by repositioning the magnetos to provide the desired retardation from the manufacturers' recommended settings.

2.4.1.1 Air-Fuel Ratio Variation

The Continental O-200 engine is a carbureted engine fitted with a Marvel Schebler MA-3 carburetor. This carburetor is a single barrel float type, contains an accelerating pump and uses an externally controllable orifice in the fuel circuit to provide the fuel cutoff capability. Only two mechanical controls are required by the carburetor: the throttle position and the mixture control push rods. Initial baseline tests indicated that the carburetor, as installed in the test circuit, would not provide a 10 to 1 air-fuel ratio at higher power modes. Discussions with the manufacturer resulted in a slight modification of the carburetor which then allowed the air-fuel ratio to be enriched to 10 to 1. The modification consisted of drilling an 1/8 inch diameter hole in the cover of the float bowl to allow ambient pressure to reach the fuel surface. The resulting slightly higher pressure differential across the main fuel metering orifice permitted the necessary fuel flow rates to be achieved.

The Lycoming IO-540 engine is equipped with a fuel injection system manufactured by Bendix. The fuel injection system is the Bendix RS-5 system,[5] which is a constant flow system providing the desired amount of fuel for the engine air flow rate. The system has individual fuel injectors (nozzles) located in each cylinder intake elbow. Each nozzle is vented to ambient (or throttle body air inlet) and the throttle body contains the necessary fuel metering servos, air pressure sensors and throttle plate. Only two external controls are required: the throttle and mixture control push rods. Discussions with the manufacturers indicated that the injection system as delivered with the engine would have to be modified slightly to provide the desired 10 to 1 air-fuel ratio over the full power range. The necessary work was provided by the manufacturer and subsequent tests verified that 10 to 1 air-fuel ratio could be obtained with the modified system. The mixture control provided full control of the air-fuel ratio, including complete fuel flow cutoff.

2.4.1.2 Ignition Timing

The Continental 0-200 engine was equipped with Slick magnetos set at the factory to 28 degrees before top dead center (BTDC). A standard magneto timing box was used to verify spark timing. The magneto case and engine crankcase were marked to provide easy reference and retiming when necessary. Marks were provided which corresponded to spark timings of 28 degrees BTDC, 23 degrees BTDC and 18 degrees BTDC as required by the test matrix. Both magnetos were marked in this manner.

The Lycoming IO-540 engine was equipped with Bendix magnetos set at 25 degrees BTDC by the engine manufacturer. As above, the magnetos and crankcase were marked to provide easy reference and setting of the magnetos to 25 degrees BTDC, 20 degrees BTDC and 15 degrees BTDC as required by the test matrix. Spark timing was preset for either engine as desired and remained fixed for the data point under observation.

2.4.2 Positive Crankcase Ventilation

Aircraft engine crankcases are normally designed to have a single opening to atmosphere to allow the blowby gases to escape from the engine. Positive ventilation (continuous flow from the atmosphere) through the crankcase is not provided as with automobile engines. The higher engine temperatures, longer operating times at high temperature and better maintenance of the aircraft engine is not as conducive to promoting oil contamination as is the case with the automobile engine.

Factors requiring special consideration in the design of crankcase gas control systems for aircraft piston engines include (1) the possible freezing of water present in the blowby gases, (2) tight limitations of crankcase-to-ambient pressure differential in a non-vented system with current seal designs, and (3) the fact that the pressure in some aircraft induction systems may exceed ambient pressure because of ram air increase or supercharging.

For the above reasons, no simple existing automotive PCV valve could be procured and adapted for the experimental program. A simulated PCV valve and circuit was assembled to permit the acquisition of PCV system data for an aircraft engine. This system is not flyable and was built strictly for evaluation on the engine dynamometer.

A schematic of the circuit is shown in Figure 2-2. The crankcase vent was communicated to a flow meter, through a control valve,

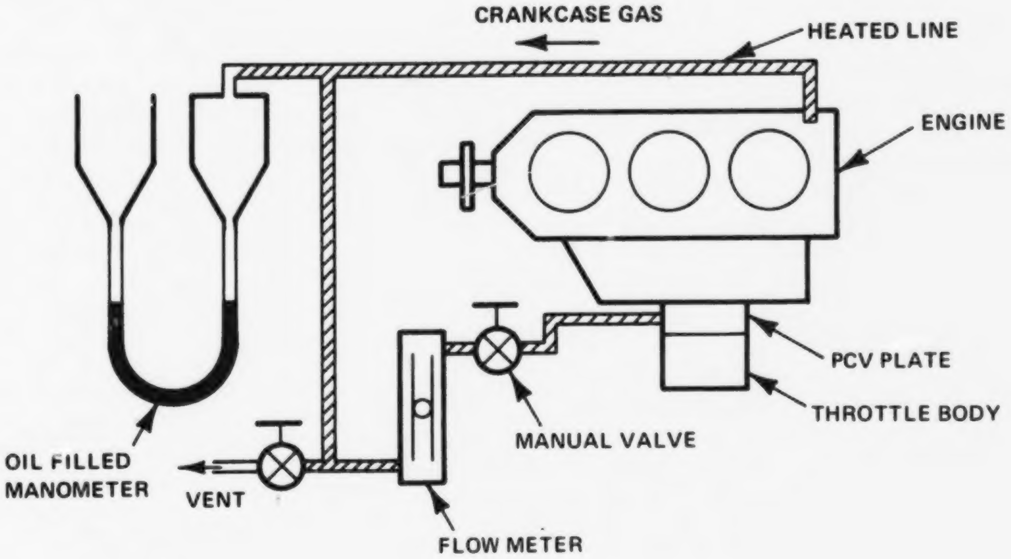


Figure 2-2 - Simulated PCV Installation - Schematic

and then back to the induction system. A special plate, approximately 1.5 inches thick was located between the induction manifold and the carburetor or throttle body for admission of the blowby gases. The connecting line was heated by electrical tape to approximately 150°F to prevent excessive water condensation in the line and flow meter.

An oil manometer, which was filled just enough to provide a maximum of ±4 inches of oil differential pressure, was used as a combination crankcase pressure sensor and safety valve. If the engine crankcase-to-ambient pressure exceeded four inches of oil, the engine would either inhale the oil or blow the oil out depending on the sign of the differential pressure. In either event no damage would be done. In normal operation the manual valve was closed and the vent opened. After the engine operating point was adjusted, the manual valve was slowly opened and the vent valve slowly closed while observing the oil-filled manometer. The process was continued until the vent valve was fully closed and the oil filled manometer read essentially zero. In this condition all the blowby gases were being admitted to the induction manifold with the manual valve providing the correct impedance for crankcase pressure control.

A photograph of the test setup is presented in Section 3.2.2 (Figure 3-7). The same setup was used for both the Continental and Lycoming engines.

2.4.3 Exhaust Treatment Systems

2.4.3.1 Continental 0-200

The Continental 0-200 engine is a four-cylinder opposed engine.[6] Each bank of cylinders exhausts through essentially a "Y"-shaped exhaust stack. Each exhaust stack contains a heat muff arrangement, one of which provides cabin heat while the other provides carburetor heat. The standard exhaust stacks used for this program are the ones supplied by Cessna on their Model 150 airframe.[7] A schematic of the standard exhaust stack system is shown in Figure 2-3. While the stacks are separate in the airplane, in the test configuration they were collected by another "Y" to provide a single exhaust to the dynamometer cell scavenge system. A single exhaust gas sampling probe was used downstream of the "Y" so that the sample was the average of all four cylinders.

Secondary air was provided by two automotive vane-type pumps. The pumps were experimental units provided by Saginaw Division of GM. It was necessary to use two pumps to provide a sufficient quantity of air for the combustion of the fuel-rich exhaust gas over the full test matrix. As shown in Figure 2-4, the output of each pump was collected, passed through a flow meter, and then manifolded to each cylinder exhaust stack. The air injector was a 1/2 O.D. tube welded into the standard exhaust stack as close to the exhaust port flange as practical. The area of the secondary air manifolding was made large compared to the effective areas of the injectors to ensure uniform distribution

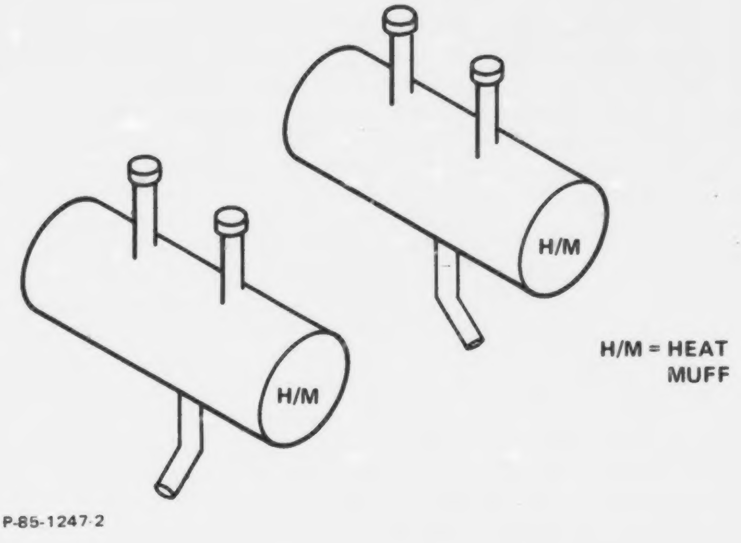

H/M
H/M
H/M = HEAT MUFF
P-85-1247-2

Figure 2-3 - Continental 0-200 Standard Exhaust System

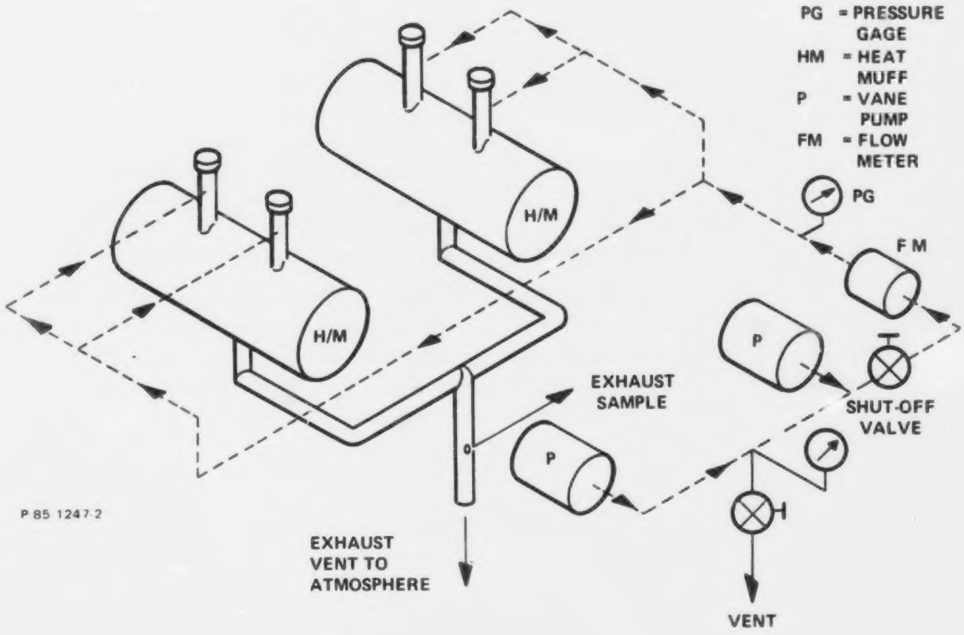

PG = PRESSURE GAGE
HM = HEAT MUFF
P = VANE PUMP
FM = FLOW METER
PG
F M
H/M
H/M
P
P
EXHAUST SAMPLE
SHUT-OFF VALVE
EXHAUST VENT TO ATMOSPHERE
VENT
P 85 1247-2

Figure 2-4 - Continental 0-200 Secondary-Air Installation

to the individual cylinders. Since the pumps were mechanically driven by the engine, a vent valve was provided to dump excess air from the system. The method of driving the pumps was through an arrangement of "V" belts and a jack shaft as shown in Figure 2-5. The pulley ratios were such that the pumps were driven at 2.1 times crankshaft speed. The entire arrangement was attached to the engine by bolting to the lower accessory drive pad on the crankcase.

The thermal reactor installation consisted of replacing the standard exhaust stacks with a thermal reactor on each bank of cylinders. As shown in Figure 2-6, the arrangement is the same as the straight secondary air system with the exception of the addition of the thermal reactors. The thermal reactors were designed by Bendix to fit the particular engine since no standard components existed for the experimental study. The designs were based on published techniques and guidelines,[8-11] and an attempt was made to keep them realistic in terms of weight and size for an aircraft application. As shown in Figure 2-7, the reactor consisted of an internally insulated pressure vessel with several concentric tubular liners which required the exhaust gas to recirculate back and forth before escaping out the exhaust stack. The exhaust gas from each cylinder was conducted to the center of the liners by tubes from each exhaust port.

The illustration indicates three exhaust ports, which is correct for the Lycoming installation. The Continental reactors had two exhaust port inlets as required by that engine. The secondary air was introduced into the exhaust collectors as far upstream into the exhaust port of the engine as possible. In fact, the entrance was flush with the cylinder exhaust flange. The thermal reactor pressure vessel was fabricated from 300-series stainless steel. The liners were fabricated from Armco 18-SR stainless (18 Cr, 0.5 Ni, 2 Al) which has demonstrated good high-temperature corrosion resistance. The insulation used was Johns-Manville "Fiberchrome" 12 lb stock. Suitable thermocouple ports were provided to indicated gas/liner temperatures during operation.

The catalytic convertor installation used the standard exhaust stacks with the two convertors installed in the exhaust lines downstream of the two heat muffs (Figure 2-8). The catalytic convertors were obtained from C.A. Englehard Co. and were their Model PTX-4 size. As shown in Figure 2-9, the catalytic convertor is a very simple design, being essentially a tubular container with means for retaining the proprietary catalytic material. A wire mesh was used for some thermal impedance and thermal expansion control with the pressure vessel. The convertors were easily installed and performed well throughout the test when operated within their specified design limits.

Photographs of the secondary air, thermal reactor and catalytic convertors test installations on the Continental 0-200 are presented in Section 3.

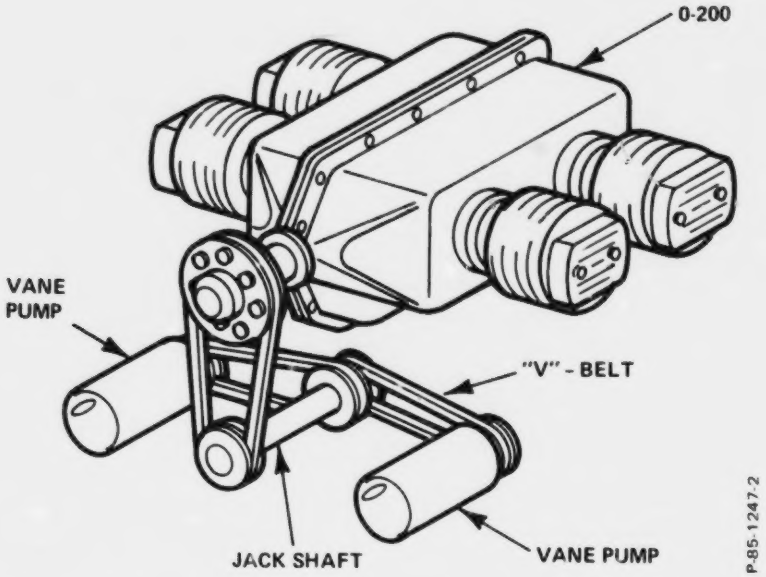

0-200
VANE PUMP
"V" - BELT
JACK SHAFT
VANE PUMP
P-85-1247-2

Figure 2-5 - Air Pump Drive on Continental 0-200 Engine

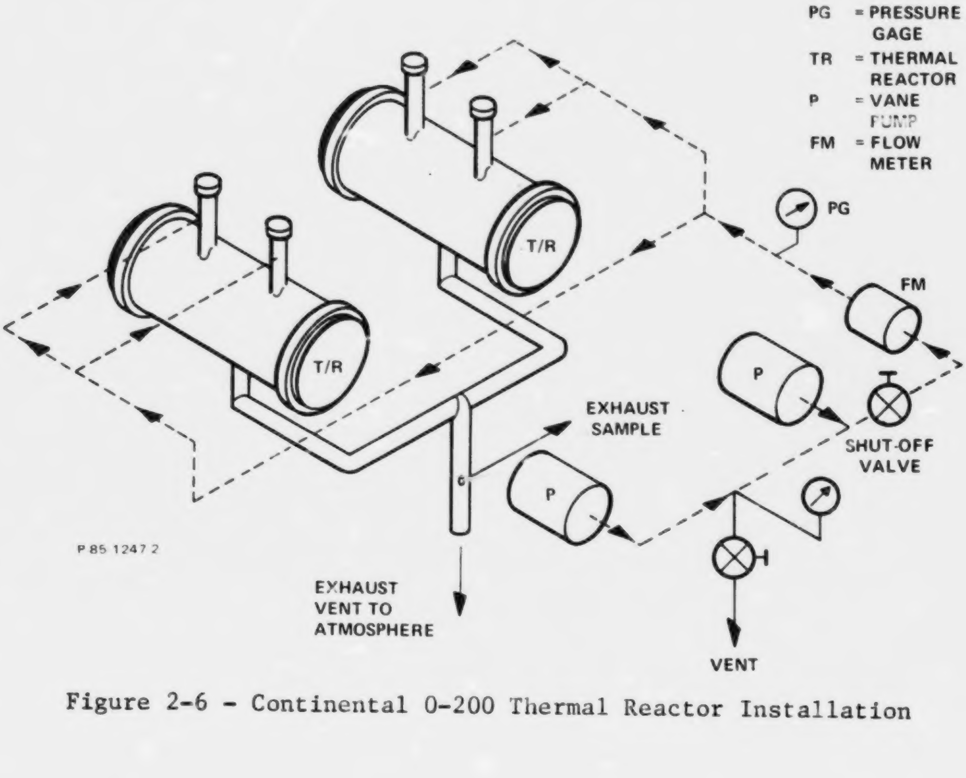

PG = PRESSURE GAGE
TR = THERMAL REACTOR
P = VANE PUMP
FM = FLOW METER
PG
T/R
T/R
FM
P
EXHAUST SAMPLE
SHUT-OFF VALVE
P
P 85 1247 2
EXHAUST VENT TO ATMOSPHERE
VENT

Figure 2-6 - Continental 0-200 Thermal Reactor Installation

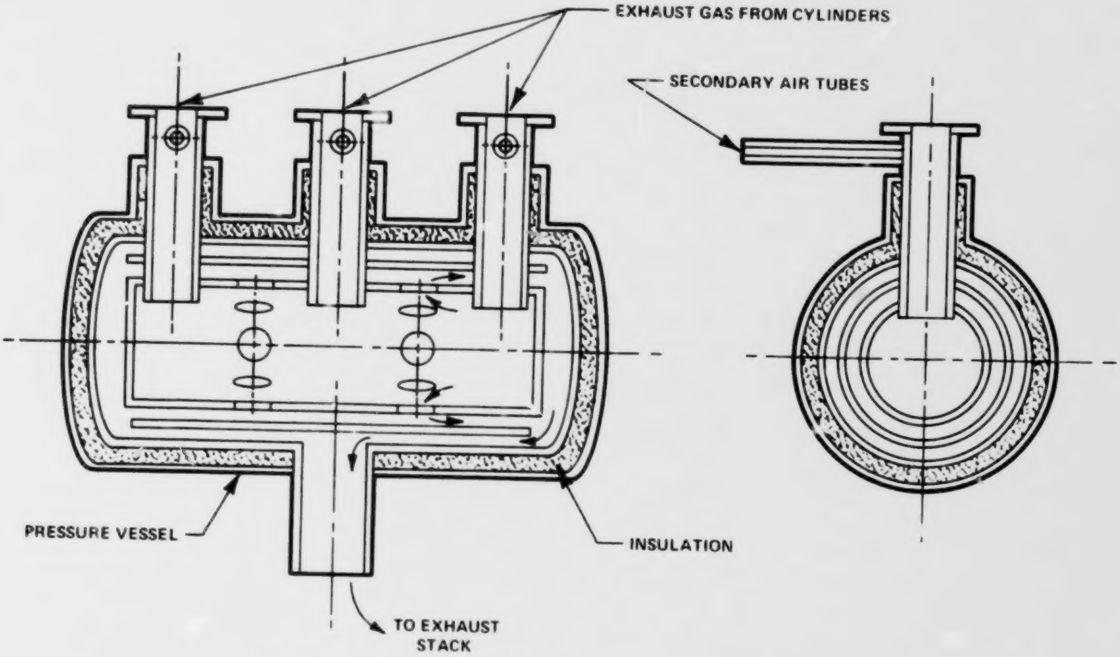

EXHAUST GAS FROM CYLINDERS
SECONDARY AIR TUBES
PRESSURE VESSEL
INSULATION
TO EXHAUST STACK

Figure 2-7 - Typical Thermal Reactor Design

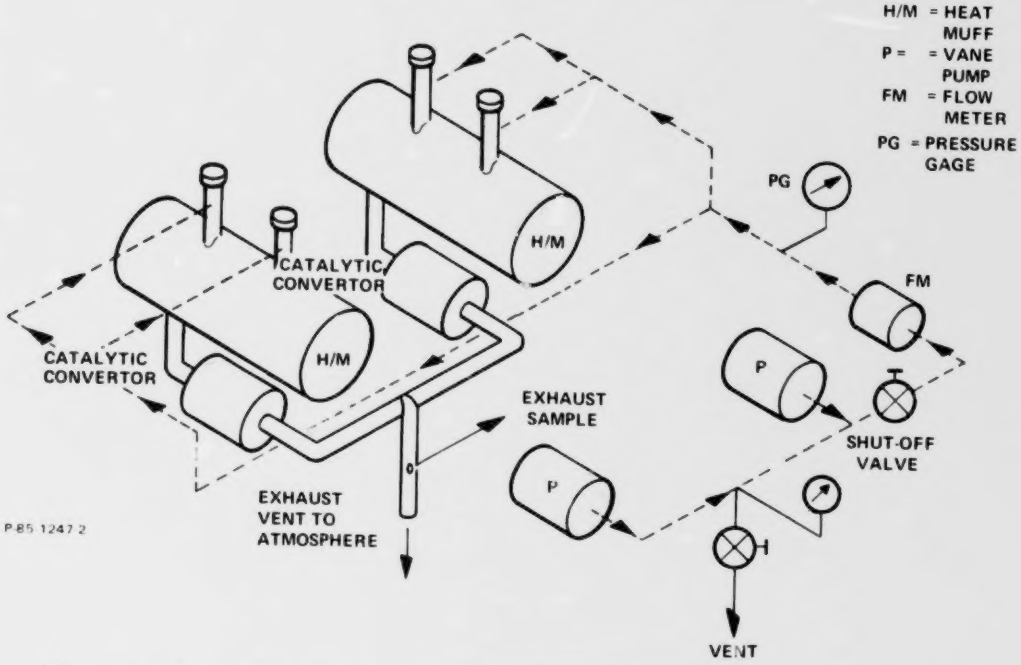

H/M = HEAT MUFF
P = = VANE PUMP
FM = FLOW METER
PG = PRESSURE GAGE
PG
H/M
CATALYTIC CONVERTOR
FM
CATALYTIC CONVERTOR
H/M
P
EXHAUST SAMPLE
SHUT-OFF VALVE
P
EXHAUST VENT TO ATMOSPHERE
P-85 1247 2
VENT

Figure 2-8 - Continental 0-200 Catalytic Convertor Installation

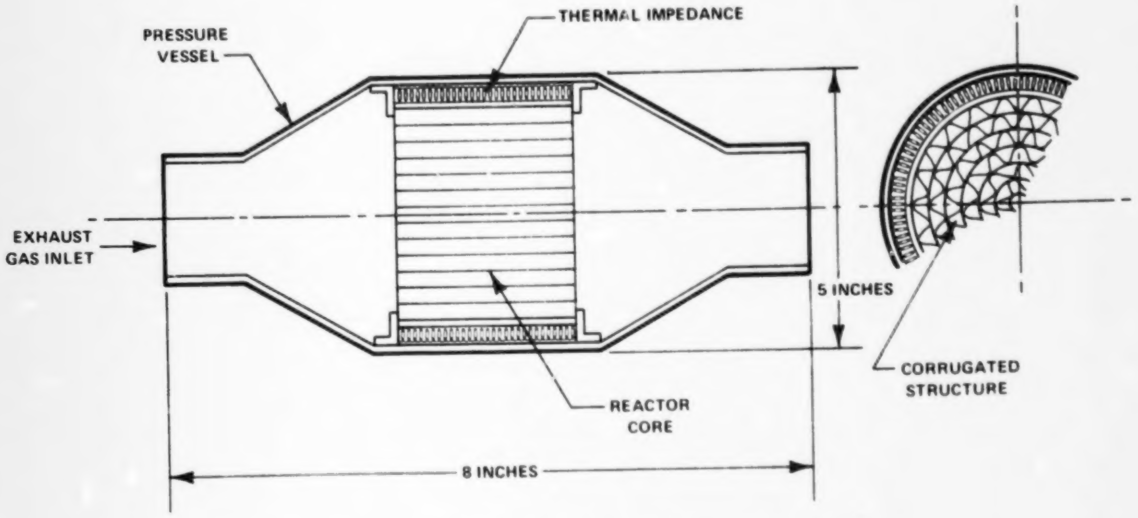


Figure 2-9 - Typical Catalytic Convertor Design

2.4.3.2 Lycoming IO-540

The Lycoming IO-540 engine is a six-cylinder opposed engine with mechanical fuel injection.[12] In the Piper PA-24 airframe installation, exhaust gases from each bank of cylinders are collected into a single tube, which is a combination heat muff and muffler.[13] A single exit tube exhausts the gases to atmosphere. Such arrangement is shown in Figure 2-10. The actual exhaust stacks and muff used for this program are those supplied for the Piper PA-24 airframe. The exhaust outlet was connected to the dynamometer scavenge system and the exhaust gas sampling probe was located in the outlet section. Thus, the exhaust gas sample was the average of all six cylinders.

The secondary air installation was somewhat similar to the Continental in that 1/2 inch O.D. injector tubes were welded into the standard exhaust stacks as close to the exhaust port flange as practical. The injectors were all manifolded back to a common inlet port as shown in Figure 2-11. The secondary air pump selected for use in this installation was an exhaust-driven turbocharger. The turbocharger selected was a Rajay RJ-0080-102 unit which is one of the two units used on a turbocharger installation in the PA-24 airframe. The test configuration used a single turbocharger for secondary air only and was in no way communicated to the induction system. The turbocharger was controlled by a typical waste gate or bypass valve which diverts the necessary exhaust through the turbocharger to provide the desired output flow of air. The output air from the turbocharger was communicated through a flow meter to the secondary air manifolding on the engine as shown. Because control of the turbocharger was expected to be somewhat coarse, a vent valve was provided for fine trim. A shutoff valve was provided to

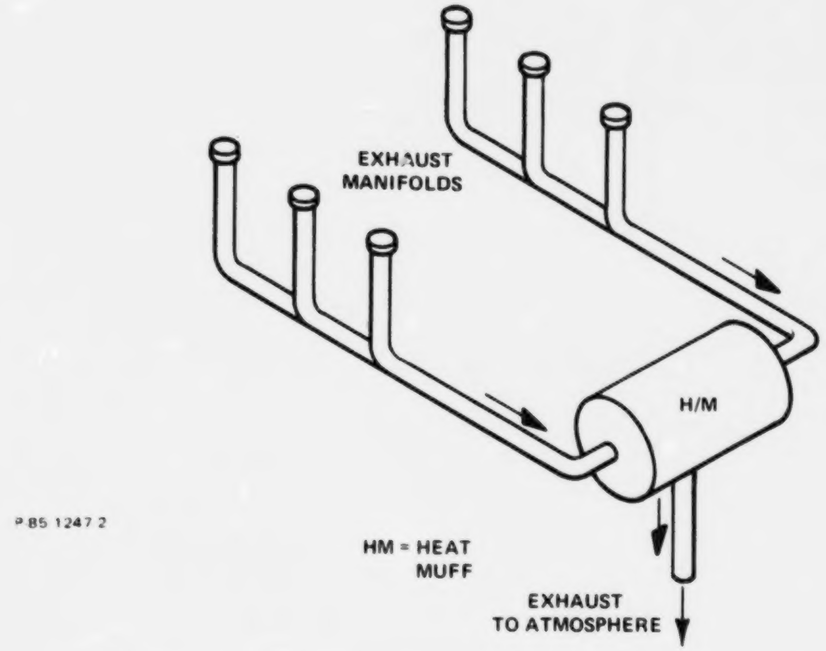

EXHAUST
MANIFOLDS
H/M
P 85 1247 2
HM = HEAT
MUFF
EXHAUST
TO ATMOSPHERE

Figure 2-10 - Lycoming IO-540 Standard Exhaust System

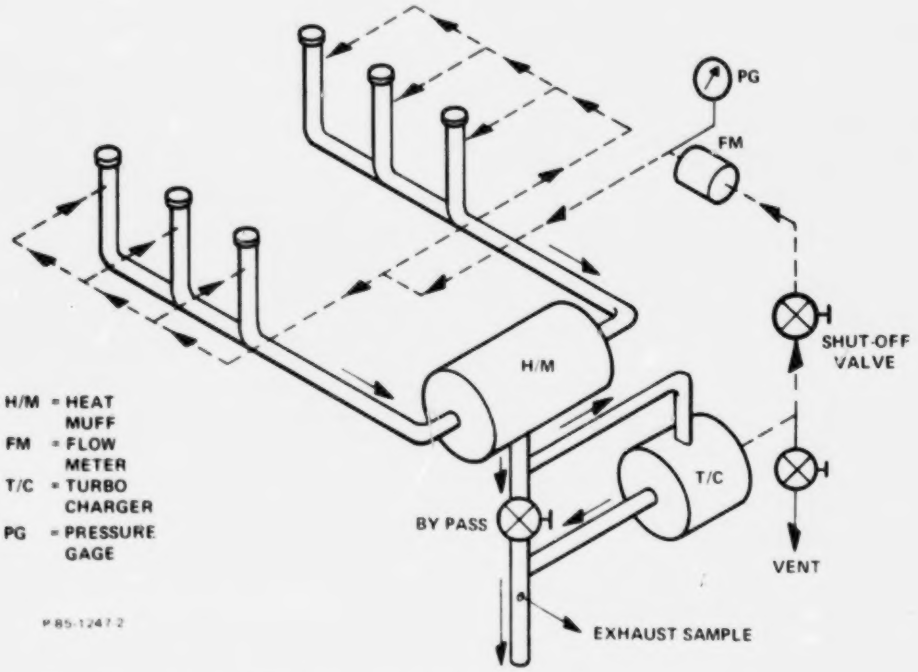

PG
FM
SHUT-OFF
VALVE
H/M
T/C
H/M = HEAT
MUFF
FM = FLOW
METER
T/C = TURBO
CHARGER
PG = PRESSURE
GAGE
BY PASS
VENT
P 85-1247.2
EXHAUST SAMPLE

Figure 2-11 - Lycoming IO-540 Secondary-Air Installation

prevent back flowing the flow meter and turbocharger when no secondary air flow was required. The exhaust sample probe was located downstream of the turbocharger exit port so that during secondary air tests, any effect the turbocharger may have had on the exhaust gases would have been present. Suitable thermocouple ports were provided to monitor secondary air injection temperature as well as turbocharger inlet and outlet temperatures.

The thermal reactor installation was as shown in Figure 2-12. The thermal reactors replaced the standard exhaust stacks while all other apparatus remained the same. The thermal reactors were similar to the ones designed for the Continental 0-200 as shown in Figure 2-7. The reactors were designed to minimize the distance the exhaust had to travel before reaching the center of the reactor. In addition, the experimental reactors were designed to be as practical as possible in terms of size and weight. Suitable thermocouple ports were provided to monitor thermal reactor gas/liner temperatures.

The catalytic convertor installation design for this engine was primarily the secondary air system with standard exhaust stacks, but with the heat muff replace by two catalytic convertors. A schematic of the system is shown in Figure 2-13. The catalytic convertors used were obtained from C. A. Englehard and were their PTX-5 model. The convertors were identical in construction to the ones used on the Continental 0-200 except that they were larger. Thermocouples were installed to monitor exhaust gas temperatures at the catalytic convertor inlets and outlet.

As indicated in Section 3.3.3 below, installation of the turbocharger in the exhaust path downstream of the injection and reaction regions led to significant regenerative effects and resultant control difficulties in the test configuration. Mounting the reactor(s) downstream of the turbocharger and locating the air injector(s) at the reactor inlet would eliminate the regenerative effect. The much-reduced inlet temperature to the reactor(s), caused by the thermal drop in the turbocharger and the increased distance from the exhaust port, would, however, probably eliminate the application of simple secondary air and thermal reactor approaches. Such an arrangement would probably be suitable and advantageous with catalytic convertors, since they can function at low inlet gas temperatures, and the lower initial temperature would allow for greater exhaust gas combustion without exceeding the maximum temperature limit of the convertor(s).

In view of the above, the location of the turbocharger should be considered thoroughly in implementing exhaust treatment systems with such devices.

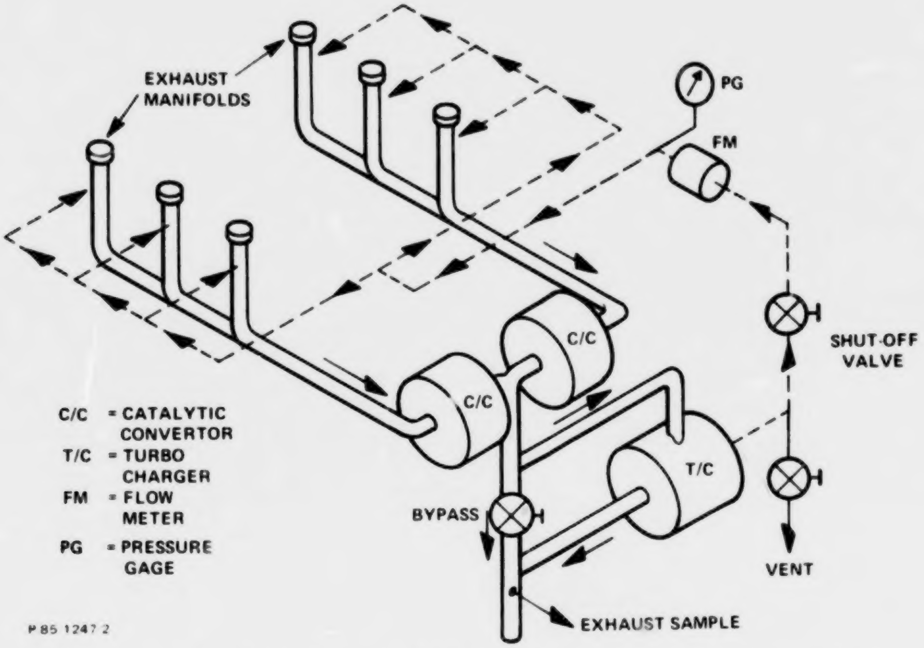

EXHAUST MANIFOLDS
PG
FM
SHUT-OFF VALVE
C/C
C/C
T/C
BYPASS
VENT
EXHAUST SAMPLE
C/C = CATALYTIC CONVERTOR
T/C = TURBO CHARGER
FM = FLOW METER
PG = PRESSURE GAGE
P85 1247 2

Figure 2-12 - Lycoming IO-540 Thermal Reactor Installation

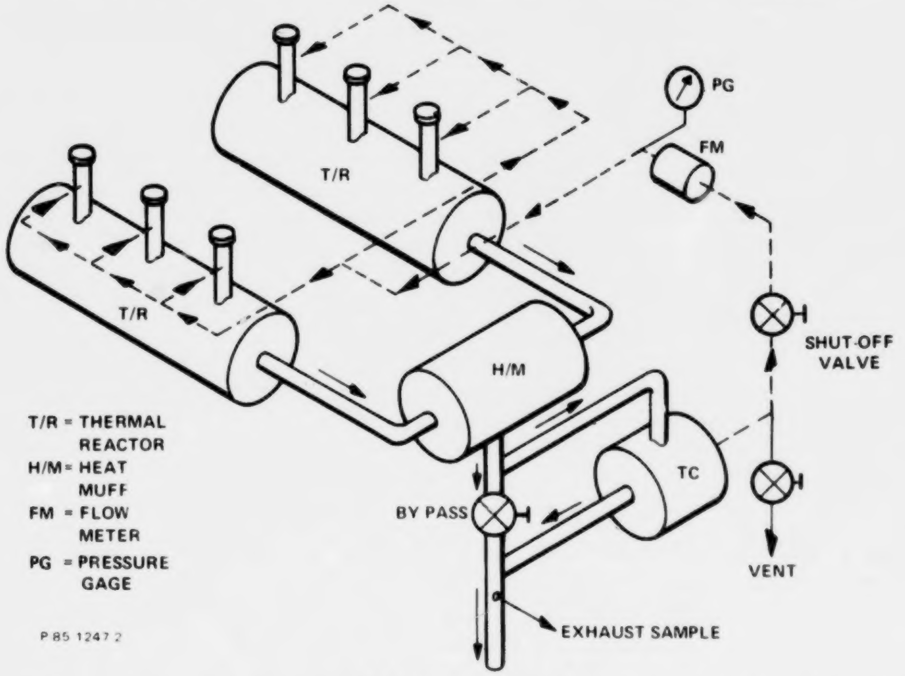

PG
FM
T/R
T/R
H/M
SHUT-OFF VALVE
TC
BY PASS
VENT
EXHAUST SAMPLE
T/R = THERMAL REACTOR
H/M = HEAT MUFF
FM = FLOW METER
PG = PRESSURE GAGE
P85 1247 2

Figure 2-13 - Lycoming IO-540 Catalytic Convertor Installation

SECTION 3

TEST EVALUATION PROGRAM

3.1 GENERAL APPROACH AND TEST SETUP

To evaluate systematically the various emission control concepts, a general matrix of conditions was selected to cover a representative combination of the variables of interest. A set of power points was selected to correspond to key portions of assumed landing-takeoff profiles for the Continental 0-200 and Lycoming IO-540 engines tested.

The selection of the ranges of air-fuel ratio and timing retardation was made primarily on the basis of a review of other aircraft engine research data publications, and discussion with the engine manufacturers. Power points (RPM's and torque levels) were selected from operator's manuals for aircraft using the subject engines where provided and were based on nominal propeller loading calculations where numbers were not published.

The following evaluations were conducted on the respective engines and systems.

Continental 0-200 Engine

Evaluation at five power settings of the effect on performance and emissions of:

- Variations in Engine Variables (A/F and Ignition Timing)
    - A/F 10, 11.5, 13
    - Ignition Timing 28°, 23°, 18°
- Positive Crankcase Ventilation
- Exhaust Treatment Systems
    - Secondary Air Injection
    - Thermal Reaction
    - Catalytic Conversion

Secondary Air Injected for 90%, 100%, 110% of Stoichiometric Mixture in the Exhaust Gas.

Lycoming IO-540 Engine

Evaluation at four power settings of the effect on performance and emissions of:

- Variations in Engine Variables (A/F and Ignition Timing)
    - A/F 10, 11.5, 13
    - Ignition Timing 25°, 20°, 15°

- Positive Crankcase Ventilation
- Exhaust Treatment Systems
  - Preliminary tests in which an exhaust-driven turbocharger was used as a secondary-air pump.

A description of those tests and their results is presented in the following sections. A detailed description of the test setup, instrumentation, and procedures is presented in Appendix A.

3.2 CONTINENTAL 0-200 EVALUATION

3.2.1 Effect of Engine Variables

Data were recorded for steady-state operating conditions with nominal air-fuel ratios of 10.0:1, 11.5:1 and 13.0:1 and ignition timing of 28° (factory setting), 23° and 18° BTDC. The following load rpm and torque conditions were used:

Mode Represented	Engine Speed (RPM)	Brake Torque (ft-lbs)	Power (BHP	Power (% Rated)
Idle/Taxi (Out)	900	21	3.5	3.5
Idle/Taxi (In)	1100	31	6.4	6.4
Runup	1700	73	23.6	23.6
Approach	1950	96	35.7	35.7
T.O./Climbout	2750	Full Throttle	86.5	86.5

With the magneto set to 28° BTDC and the engine warmed up, the engine was set to the desired speed, torque and air-fuel ratio. Sampling of exhaust gas composition was started after the operating conditions were stabilized. The air-fuel ratio was varied at each engine speed to obtain the desired A/F test set points.

The following sequence of test conditions was used:

Speed - 1700, 1100, 1950, 900, 2750 rpm

Air-Fuel Ratio - 10:1, 11.5:1 and 13:1

The same conditions were repeated at ignition timings of 23° BTDC and 18° BTDC to complete the test series.

The five modes of the formal LTO cycle are represented by the 900, 1100, 1950 and 2750 rpm points as indicated. The 1700 rpm RUNUP mode is not part of the LTO cycle and to avoid confusion, data at that condition are not included in the discussions and analyses of emissions which appear in Section 3.2 and 4.3.

Results

Data and computed values for all test points are presented in Appendix B1. Test points marked "R" on the data sheets are points where conditions and data were repeated at a later time to establish a measure of the repeatability of engine and instrumentation conditions.

Air-Fuel Ratio Variation

The effects of variations of air-fuel ratio on engine emissions, temperature, and brake specific fuel consumption are summarized in Figure 3-1, 3-2, and 3-3, respectively. To provide the best representation of the engine's emission characteristics, plots of Figures 3-1 through 3-3 are averages of all appropriate data obtained for the conditions noted (i.e., Appendix B2 with zero PCV and Appendices B3, B4 and B5 with zero secondary air.)

As indicated in Figure 3-1, as A/F is varied from 10 to 13, total hydrocarbons (THC) and carbon monoxide (CO) drop and oxides of nitrogen (NO_x) increase. The curves shown are consistent with known general characteristics for piston engines operating below stoichiometric ratios as shown on Figure 2-1. Emissions data are presented in units of pounds per hour to best indicated the relative importance of various modes of the LTO cycle.

As indicated in Figure 3-1, the effect on total hydrocarbons of increasing A/F from 10 to 13 is greater at Idle/Taxi conditions than at Takeoff-Climbout conditions. The reduced effect of a leaner mixture at higher power conditions is believed to be caused by the generally higher combustion temperature and the reduced effect of exhaust gas dilution of the fresh charge. In addition, maldistribution may be more pronounced at part throttle settings.

The formation of carbon monoxide is largely a function of the availablity of oxygen relative to the fuel and is thus inversely proportional to A/F for values richer than stoichiometric. The decrease in CO emission rate as a function of RPM shown in Figure 3-1 is caused by the reduced fuel and air flow needed to meet the power requirements for the respective modes. The 2750 rpm curve is at wide open throttle (WOT) conditions and the drop off as A/F is reduced is because of reduced maximum power for those conditions caused by non-standard temperature and pressure conditions at the inlet.

The curves for NOx show the rapid increase in NO_x formation because of increasing peak conbustion temperature as stoichiometric air-fuel ratio is approached. Temperatures at the low power points (900 and 1100 rpm) are generally so low even with an A/F of 13 that the concentrations and emission rates remain relatively low.

The effect of air-fuel ratio on engine temperatures is shown in Figure 3-2. Variations of average cylinder head temperature (CHT) and exhaust gas temperature (EGT) are shown for A/F in the range of 10 to 13.

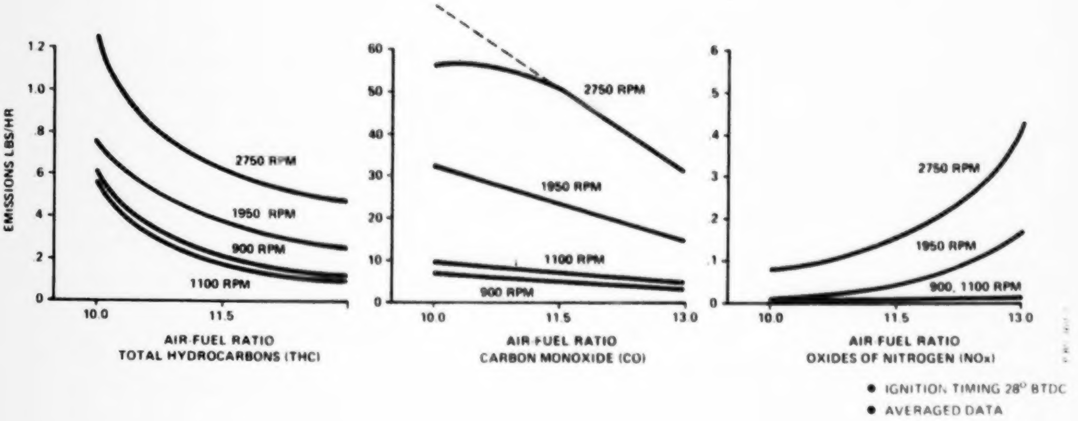


Figure 3-1 - Emissions versus Air-Fuel Ratio - Continental 0-200 Engine

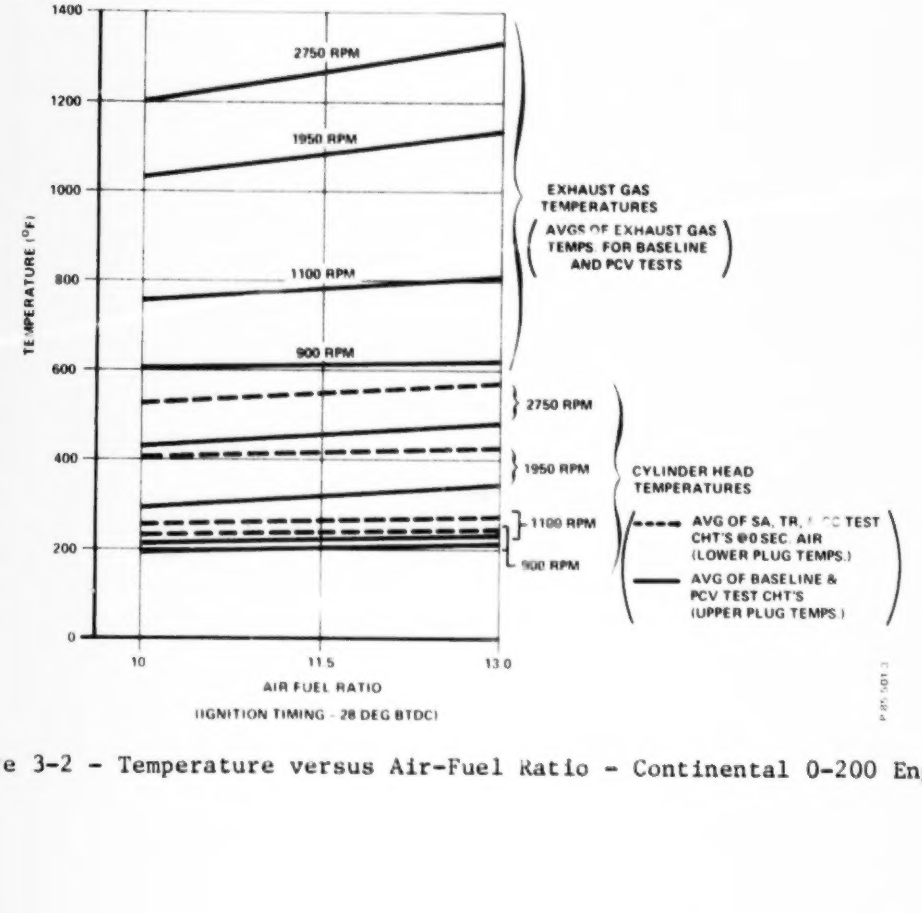


Figure 3-2 - Temperature versus Air-Fuel Ratio - Continental 0-200 Engine

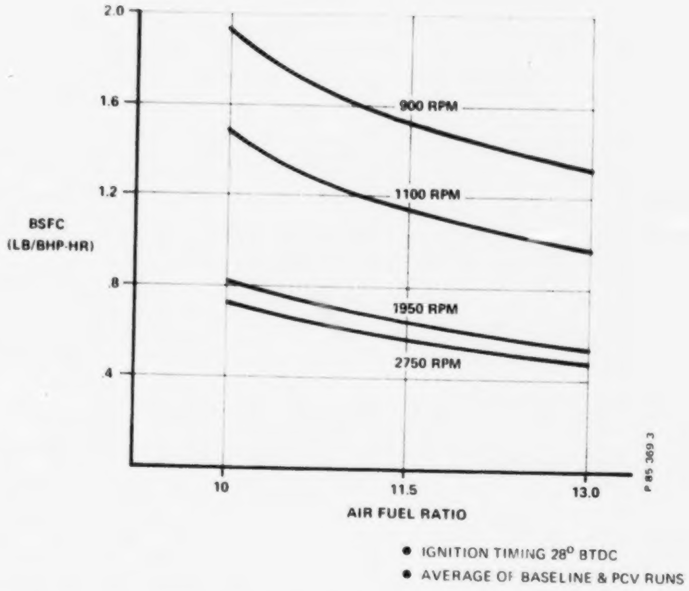


Figure 3-3 - Brake Specific Fuel Consumption versus Air-Fuel Ratio - Continental 0-200 Engine

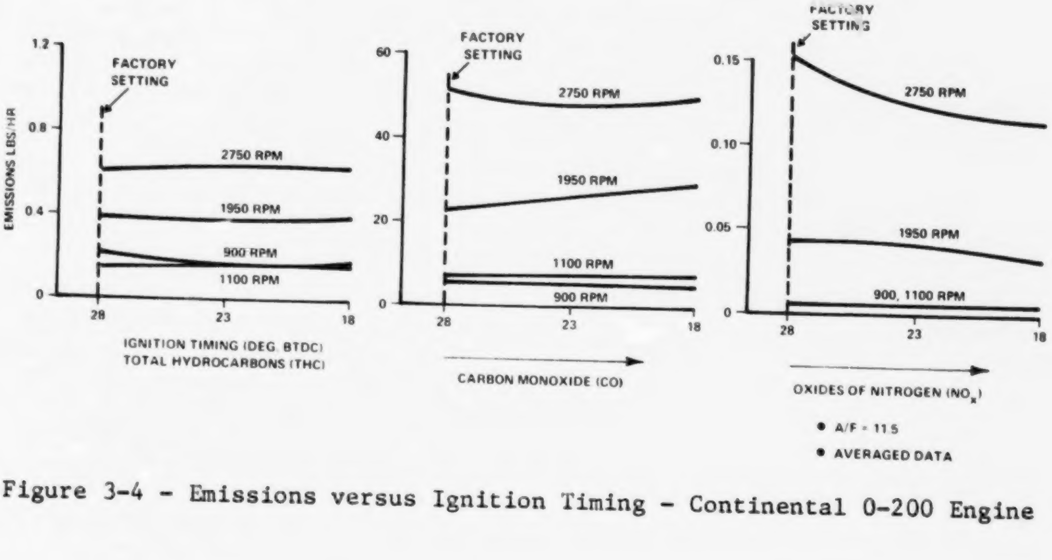


Figure 3-4 - Emissions versus Ignition Timing - Continental 0-200 Engine

The lower curve of each set of CHT's is based on averages of upper spark plug temperature (hottest cylinder) taken during the engine variables matrix and PCV test series (Appendices B1 and B2). The upper curve of each set of CHT's is the average of all CHT's measured on the lower plugs of all cylinders during the secondary air, thermal reactor, and catalytic convertor test series with zero secondary air. The differences in temperature are due to thermocouple location. Cooling air conditions were the same for all similar test points.

The effect of air-fuel ratio on brake specific fuel consumption for the various mode power conditions is shown in Figure 3-3. The improvement in fuel economy as A/F is increased from 10 to 13 is to be expected, and would normally continue for ratios approaching stoichiometric and slightly above.

Ignition Timing Variation

The effects of varying the ignition timing on engine emissions, temperature and brake specific fuel consumption are shown in Figures 3-4, 3-5, and 3-6, respectively. Curves are based on average data as indicated.

As shown in Figure 3-4, retarding the ignition timing from the normal recommended value of 28° BTDC to 18° BTDC (10° retard) results in negligible change in THC. A slight net increase in CO is indicated for the 1950 rpm case but the effects at other power conditions are minimal. NO_x is seen to decrease with retarded timing, primarily at the higher power conditions most conducive to NO_x formation.

The effect of retarded timing on engine temperatures is shown in Figure 3-5. Delaying the spark has the effect of moving the peak of the combustion process in the direction of the exhaust portion of the engine cycle. This results in a higher exhaust gas temperature because of the delayed burning and a consequent slightly reduced cylinder head temperature, as evidenced in the data of Figure 3-5.

The magneto setting recommended by the engine manufacturer is normally selected for best overall BSFC and performance, and the slight increase in BSFC with retard reflects the consequent reduction in efficiency.

The above data indicate that retarding the timing results in negligible effect on THC and a slight increase in CO over the range tested. Since the NO_x levels were not high enough to be of concern, the relative reduction experienced is not immediately valuable. Since the net effect on emissions is not significant and there are undesirable increases in both engine temperature and BSFC, the tests suggest that delayed ignition timing alone would not be a useful technique for exhaust emission control in the range tested. (As indicated in Section 3.2.3, delayed ignition timing may be useful in extending the range of operation of exhaust treatment systems.)

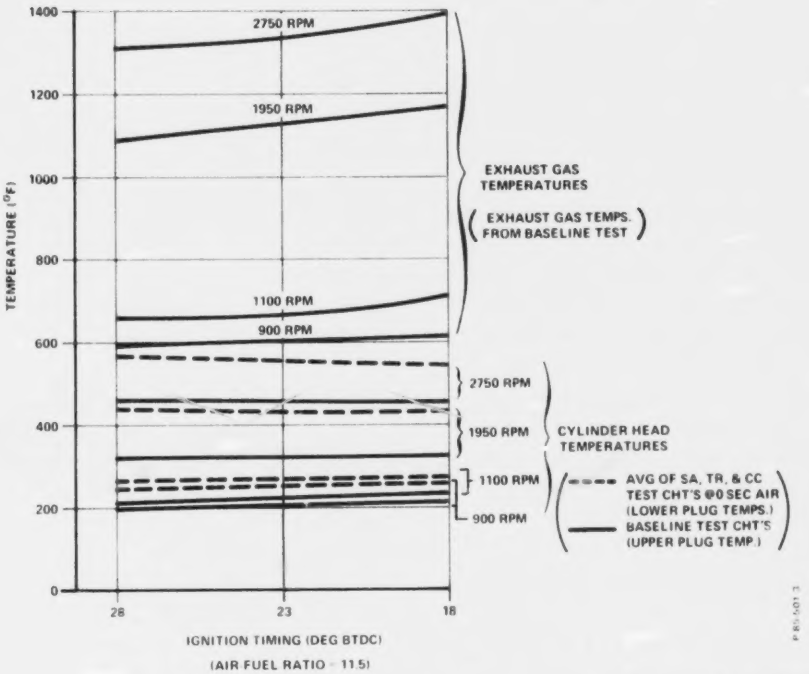


Figure 3-5 - Temperature versus Ignition Timing - Continental 0-200 Engine

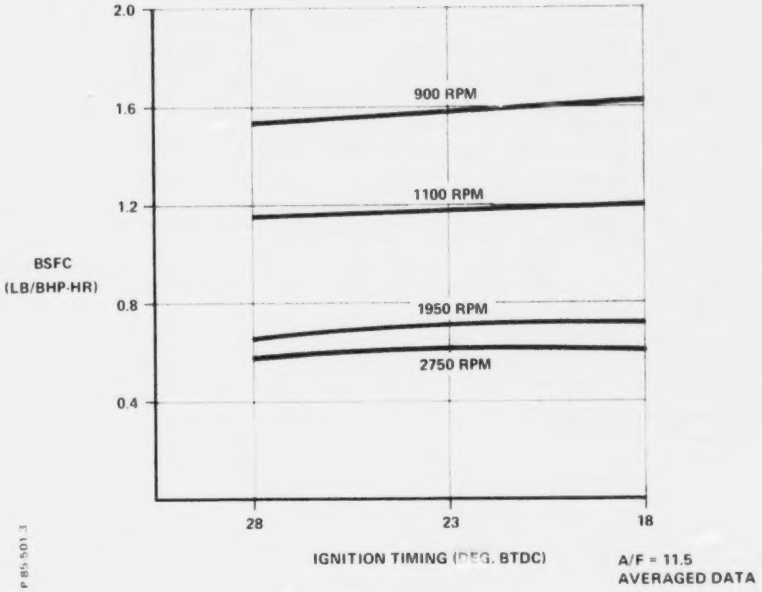


Figure 3-6 - Brake Specific Fuel Consumption versus Ignition Timing - Continental 0-200 Engine

3.2.2 Effect of PCV

Test Setup and Procedure

As explained in Section 2.4.2 above, special constraints of aircraft application prevent use of a simple automotive-type PCV valve for venting an aircraft engine crankcase. For test purposes the effect of PCV on the Continental 0-200 engine was observed by communicating the crankcase vent flow to an input block inserted between the carburetor and the intake manifold. Crankcase gas was directed to the intake manifold and/or to atmosphere by an arrangement of manual valves in such a way that crankcase pressure was maintained well within the limits of ±4 inches of water recommended for the Continental engine.

A schematic and a photograph of the test setup used are shown in Figure 3-7. The PCV lines were heated to approximately 150°F to avoid condensation in the lines and flow meter. The remainder of the test instrumentation was the same as for the engine variables tests of Section 3.2.1 above.

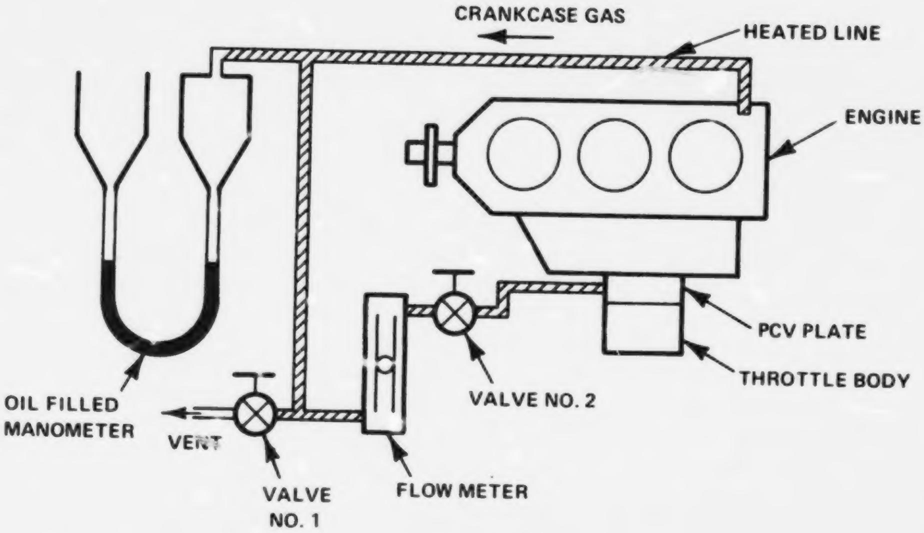
The test procedure consisted of setting the desired engine parameters with the crankcase vented to atmosphere by opening valve No. 1 and closing valve No. 2 in Figure 3-7. After recording the data, the crankcase gas was introduced into the intake system by closing vent valve No. 1 and adjusting valve No. 2, such that the crankcase pressure was maintained at approximately zero differential pressure as indicated by the oil manometer. The manometer was designed to function as a pressure relief in that the oil would be displaced out of the U-section, opening a path to atmosphere if crankcase pressure inadvertenly exceeded ±4 inches of water. Emission data were then recorded for the case with PCV, completing the data for that test point.

Data were taken at 900, 1100, 1700, 1950 and 2750 rpm at nominal air-fuel ratios of 10.0:1, 11.5:1 and 13.0:1 with the normal ignition (magneto) setting at 28° BTDC. Data were taken at 900 rpm, A/F = 10.0:1; 1700 rpm, A/F = 11.5:1 and 2750 rpm, A/F = 13.0:1 for retarded magneto settings of 23 degrees BTDC and 18 degrees BTDC to observe the effect of PCV at these ignition timings.

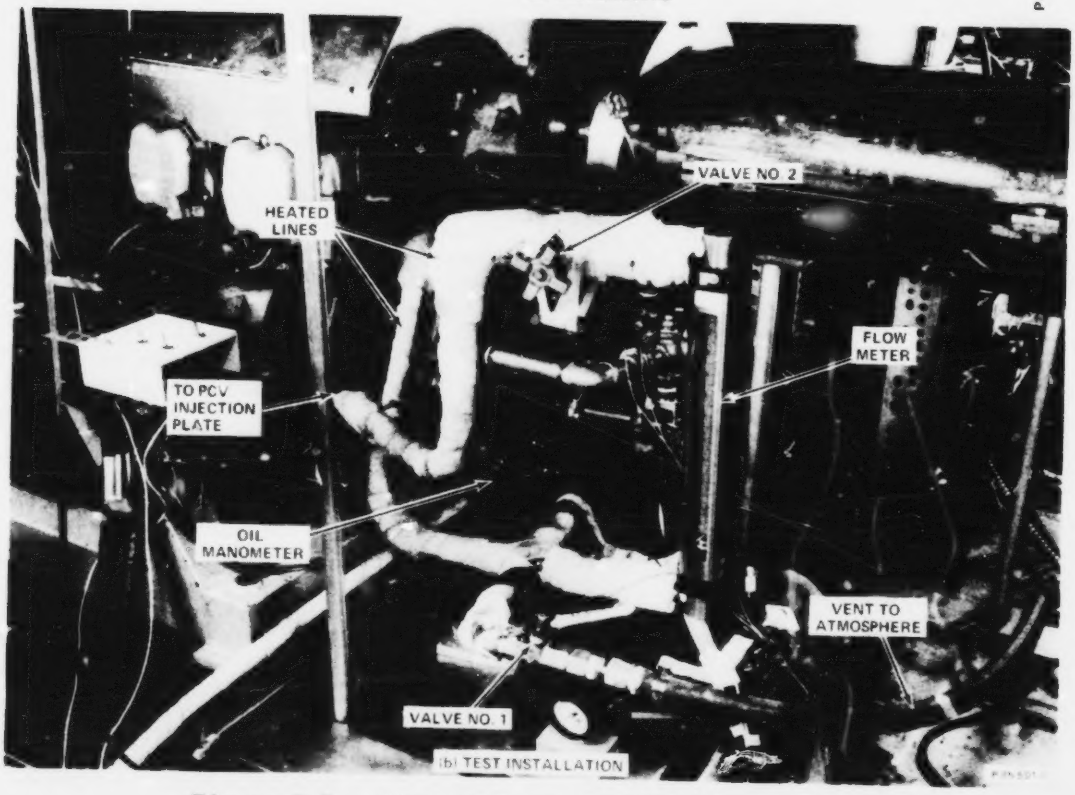
Engine test and reduced emissions data are presented in Appendix B2. The test points marked "P" on the data sheets are with PCV and the ones with "R" are repeat runs to check the repeatability of the engine and instrumentation.

Results

In general exhaust stack emissions with and without PCV were relatively unchanged at all operating modes. Significant effects were noted only at 2750 rpm and A/F = 10 where hydrocarbons were approximately 40 percent higher and NO_x was approximately 20 percent lower with PCV, suggesting that combustion temperature may have been reduced at that test condition.


CRANKCASE GAS
HEATED LINE
ENGINE
PCV PLATE
THROTTLE BODY
VALVE NO. 2
OIL FILLED MANOMETER
VENT
VALVE NO. 1
FLOW METER
P-85-501-3

(a) SCHEMATIC


VALVE NO. 2
HEATED LINES
FLOW METER
TO PCV INJECTION PLATE
OIL MANOMETER
VENT TO ATMOSPHERE
VALVE NO. 1

(b) TEST INSTALLATION

Figure 3-7 - Simulated PCV Installation for Test

The effect of PCV on engine power was also observed to be small in that engine output power (output torque at constant speed) remained essentially at the baseline setting when PCV was introduced and required no readjustment of the fuel and air inputs. The effect of PCV on manifold pressure is shown in Table 3-1. The slight pressure increase (approximately 0.5 in Hg) can be accounted for by the additional flow into the intake manifold.

Table 3-1 also summarizes the effect of PCV on THC emissions for various loads and air-fuel ratios at the 28° BTDC ignition setting. Average data published by Scott Research Laboratories is included to indicate a nominal percent of total THC emissions contributed by the crankcase flow at the various load conditions. Assuming the Scott data are applicable for this case, the approximate effect of PCV on reducing total engine emissions (last column, Table 3-1) is obtained by combining the percent change in exhaust stack emissions with the percent crankcase THC, assuming the elimination of all direct crankcase emissions. For such an assumption, the net effect of PCV is a reduction in total engine THC emission for all but one of the cases calculated.

3.2.3 Effect of Exhaust Treatment Systems

Test Setup and Procedure

The test installation for evaluation of exhaust treatment systems on the Continental 0-200 engine utilized two parallel air pumps, belt-driven off the engine output shaft to provide the required air.

Table 3-1 - Effect of PCV on Emissions - Continental 0-200 Engine

ENGINE CONDITION		W/O PCV		W/PCV		PERCENT CHANGE IN THC W/PCV (EXHAUST GAS)	PERCENT CONTRIBUTION OF CRANKCASE TO TOTAL EMISSIONS*	APPROXIMATE NET CHANGE IN TOTAL THC W/PCV
RPM	A/F	THC(PPM)	MAP IN.HG.	THC(PPM)	MAP IN.HG.			
900	10	20,306	12.7	19,889	13.15	-2.0	+6.4 (AVERAGE OF IDLE/LOW AND TAXI MODES)	-8
	11.5	9,992	11.7	9,789	11.9	-2.0		-8
	13	6,020	11.5	6,069	11.9	+0.8		-6
1100	10	17,916	13.5	17,234	13.8	-3.8	+9.4 (TAXI)	-13
	11.5	5,017	12.6	4,706	12.9	-6.1		-15
	13	3,070	12.25	3,059	12.5	-0.3		-10
1950	10	6,425	21.3	6,769	21.7	+5.3	+24.6 (APPROACH)	-19
	11.5	3,815	19.8	3,757	20.2	-1.5		-26
	13	2,305	19.8	2,297	20.0	-0.3		-25
2750	10	6,760	28.2	9,558	28.2	+41.3	+20.3 (CLIMB)	+21
	11.5	2,431	28.2	2,621	28.2	+7.8		-12
	13	2,023	28.2	1,918	28.2	-5.1		-26

*BASED ON DATA FROM "FINAL REPORT – A STUDY OF AIRCRAFT POWERPLANT EMISSIONS," SCOTT RESEARCH LABORATORIES, INC. (2) SECTION 7.3, p. 7-44

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[2] Section 7.3, p. 7-44.

For evaluation of simple secondary air injection, air flow was introduced into the engine exhaust system through injection tubes installed in the exhaust stacks between the engine exhaust ports and the standard engine exhaust heat muffs. For thermal reactor evaluation, the Continental 0-200 standard heat muffs were replaced with thermal reactors and secondary air was injected into the exhaust ports by injectors incorporated in the reactor design. Reactor core temperature was monitored by a thermocouple. For evaluation of catalytic conversion, the standard heat muffs were reinstalled and catalytic convertors were reinstalled and catalytic convertors were inserted into the exhaust paths downstream of the heat muffs between the muffs and the exhaust "T".

Schematic diagrams of the secondary air, thermal reactor and catalytic convertor installations are shown in Figures 2-4, 2-6, and 2-8, respectively, of Section 2.4.3. Photographs of the setups as implemented are shown in Figures 3-8, 3-9 and 3-10.

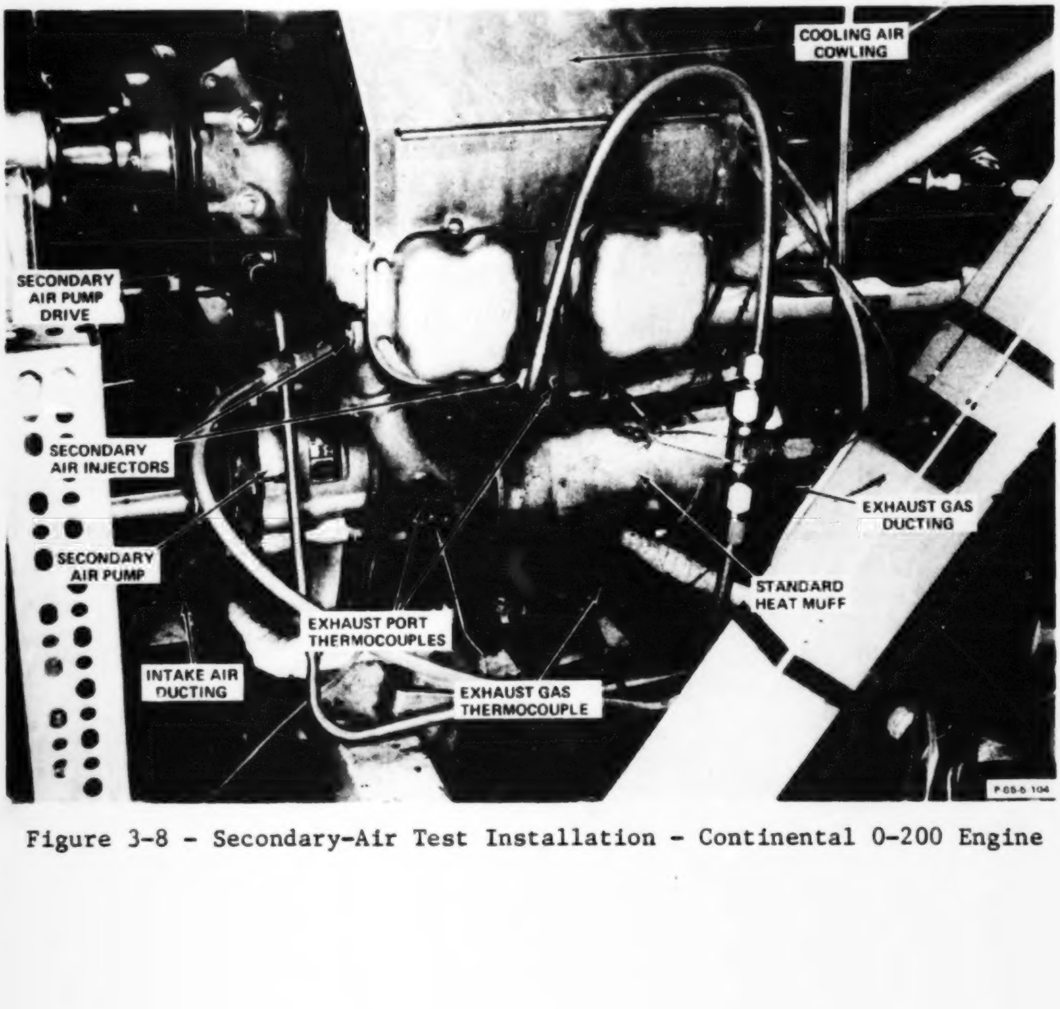
COOLING AIR COWLING
SECONDARY AIR PUMP DRIVE
SECONDARY AIR INJECTORS
EXHAUST GAS DUCTING
SECONDARY AIR PUMP
STANDARD HEAT MUFF
EXHAUST PORT THERMOCOUPLES
INTAKE AIR DUCTING
EXHAUST GAS THERMOCOUPLE

Figure 3-8 - Secondary-Air Test Installation - Continental 0-200 Engine

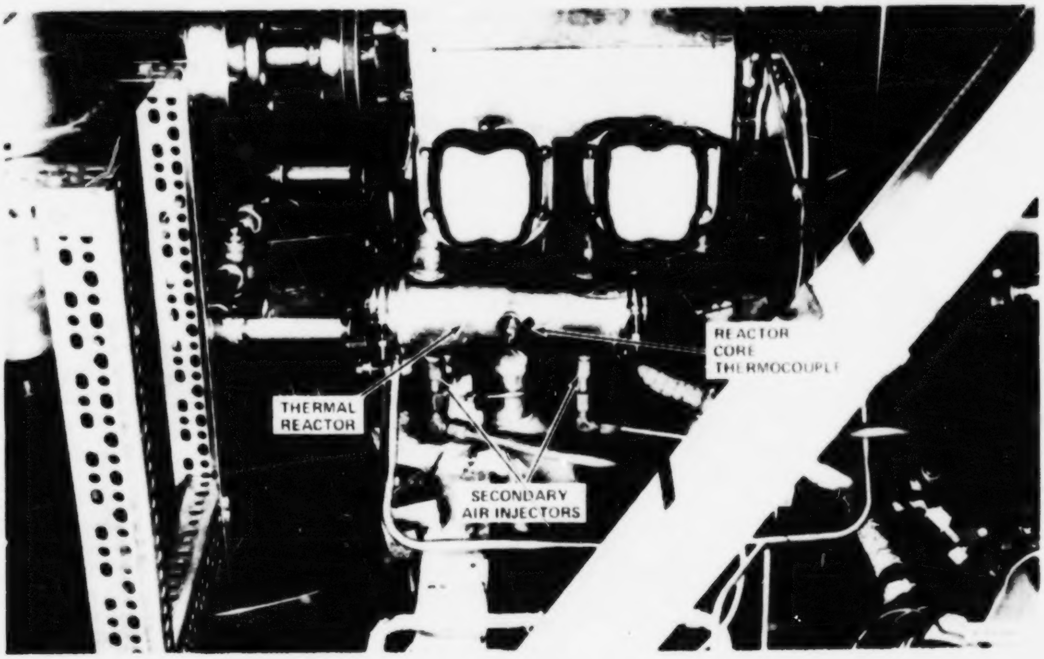
REACTOR
CORE
THERMOCOUPLE
THERMAL
REACTOR
SECONDARY
AIR INJECTORS

Figure 3-9 - Thermal Reactor Test Installation - Continental 0-200 Engine

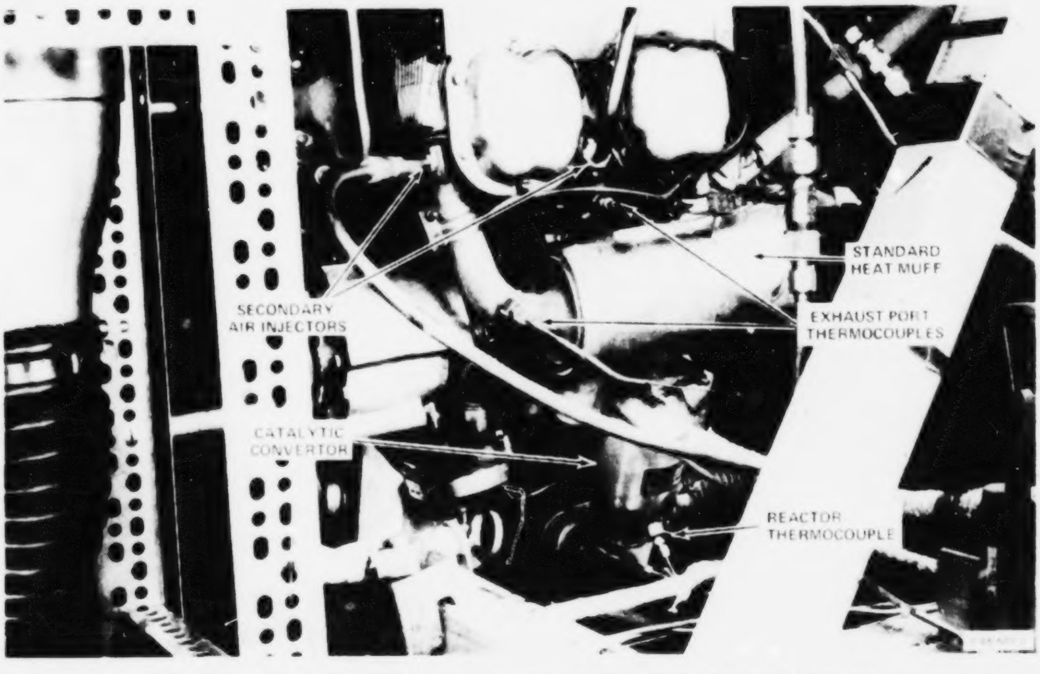
STANDARD
HEAT MUFF
SECONDARY
AIR INJECTORS
EXHAUST PORT
THERMOCOUPLES
CATALYTIC
CONVERTOR
REACTOR
THERMOCOUPLE

Figure 3-10 - Catalytic Convertor Test Installation -
Continental 0-200 Engine

As with the PCV system evaluation, the effect of the respective exhaust treatment approaches was measured at each test point by taking data without secondary air to establish a fresh baseline data point and then immediately following that measurement with the secondary air test. Secondary air was introduced at each test condition (RPM, torque, A/F ratio, ignition setting) to bring the exhaust gas composition to the equivalent of 90 percent, 100 percent, and 110 percent of the stoichiometric value of 14.7:1. The method of calculating the required secondary air flow for the various conditions is discussed in Appendix A-4.10.

The major functional difference between the three approaches is in the exhaust gas temperature required to effectively start the process. In all three approaches, the process is self-sustaining once "light-off" occurs. Theoretically, the secondary air and thermal reactor approaches require the same exhaust gas temperature to start the process. Practically, the improved mixing and temperature environment provided by the more complex thermal reactor leads to "light-off" over a wider range than achievable with straight injection into a standard manifold. A major advantage of the oxidizing catalytic convertor is that it provides catalytic action which stimulates the combustion process, allowing "light-off" and consequent emission reduction at much lower initial temperatures. Since the exhaust temperature is inadequate for "light-off" at lower power and load conditions with injected air alone, a catalytic convertor extends the range of effective emission reduction into the low-power operation region.

In all three approaches, the burning of hydrocarbons and conversion of CO to CO_2 results in heating of the system to a degree proportional to the amounts of HC and/or CO converted. The upper limit of temperature allowed for test of the secondary air and thermal reaction approaches was established by consideration of the metals used in the exhaust and/or thermal reactor system. Continental recommended a maximum temperature of a 1600°F be observed in the standard "heat muff" of the Continental 0-200 engine. A temperature limit of 1800°F was selected by Bendix for the exhaust tubing of the test setup. The thermal reactor was also allowed to approach 1800°F because of higher-temperature materials used in that design.

High temperature has at least two major effects on the catalysts used in this test evaluation. Extended operation at temperatures in the range of 16-1800°F significantly raises the minimum "light-off" temperature, reducing the temperature range of effectiveness of the catalyst. High-temperature stresses also can result in structural failure of the catalyst elements, which apparently occurred in one catalytic convertor.

Test evaluation of the secondary air injection was conducted first, followed by test evaluation of the thermal reactors. Both test series were conducted using 80/87 leaded (0.32 ml/gal) aviation gasoline. Since lead rapidly degrades a catalytic convertor (within hours), tests of the catalytic convertor were conducted on 90/100 "Alkylid", a non-leaded test fuel (0.001 ml/gal). When review of the first secondary-air test series indicated shortcomings in the test procedure, a second secondary-air test was conducted in the interim between the thermal reactor and catalytic convertor evaluations while the engine and fuel control systems were being purged on lead-sterile fuel in preparation for the catalyst tests. A total running time of approximately eight hours was expended to purge the engine and test system of lead. Comparison of baseline data confirmed that the emissions characteristics of the two fuels were essentially identical.

Test Results

Data obtained on the three emission control approaches, along with reduced and calculated values for emissions, are presented in Appendices B-3, B-4, and B-5. Test points marked "R" on the data sheets are points where conditions and measurements were repeated at a later time to establish the repeatability of engine and instrumentation conditions.

Data were obtained over the complete test matrix of 900, 1100, 1700, 1950, and 2750 rpm; and 10:1, 11.5:1, and 13:1 A/F; for the 28° BTDC ignition timing case, except where disallowed by excessive temperature rise or backfiring. Data were limited to those conditions near or where light-off occurred for the 23° and 18° BTDC retarded ignition-timing cases. In addition, the test matrix for the catalytic convertor was limited to the 28° and 23° BTDC ignition cases because of failure of one convertor at the start of the 18° BTDC test series.

The way in which light-off is enhanced in proceeding from simple secondary air injection, through thermal reaction, to the use of catalytic convertors is presented graphically in the matrix tables of Figure 3-11. The dependence of light-off on adequate exhaust gas temperature and available oxygen is clearly shown in that the matrix progressively fills for (1) higher power, (2) increasing ignition retardation, and (3) increasing amounts of secondary air. Referring to Figure 3-11, for secondary air, the exhaust gas temperature is too low at the 900 and 1100 rpm cases for light-off to occur with any of the combinations of secondary air or spark retard used. Temperatures for 1700 rpm operation appear to be marginal and the amount of secondary air, engine A/F, and spark retard can influence whether or not light-off occurs. The general effects are the same for the thermal reactor data except that there is a general increase in the number of load conditions where light-off occurs because of the better thermal conditions provided by the reactors at the exhaust ports. The matrix provided for the catalytic convertor shows that light-off occurred for all load conditions and ignition timing cases tested.

Once substantial "light off" occurs, the reduction of THC and CO content is influenced by the amount of oxygen present relative to

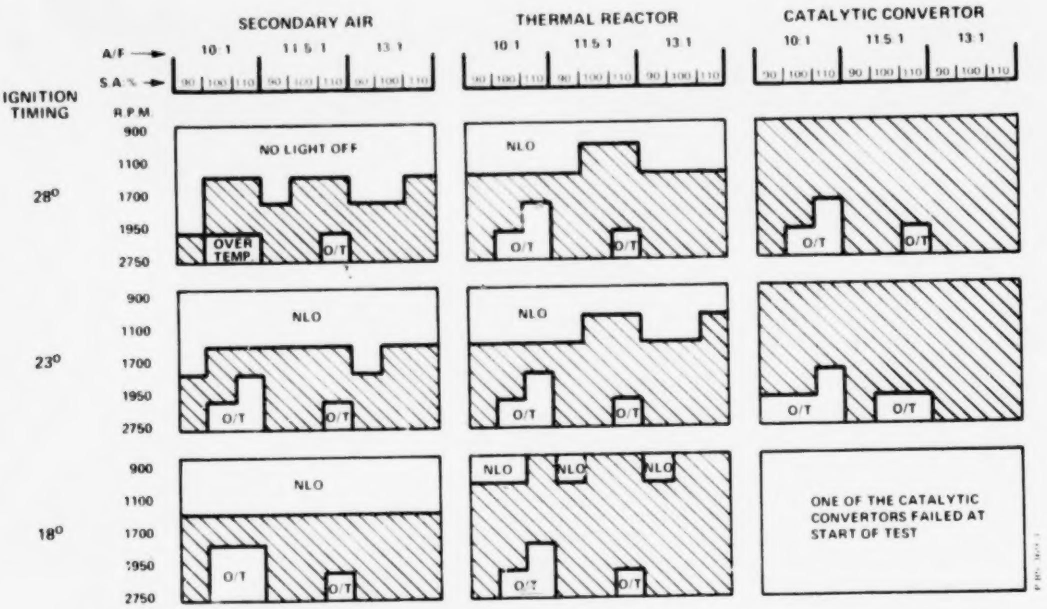
SECONDARY AIR
THERMAL REACTOR
CATALYTIC CONVERTOR
A/F
S.A.%
IGNITION TIMING
RPM
10:1
11.5:1
13:1
90
100
110
900
1100
1700
1950
2750
28°
23°
18°
NO LIGHT OFF
NLO
OVER TEMP
O/T
ONE OF THE CATALYTIC CONVERTORS FAILED AT START OF TEST

Figure 3-11 - Exhaust Treatment System: Effectivity Matrix for Continental 0-200 Engine

emissions, the temperature and general thermal profile during the combustion process, the duration of the combustion procuss (residence time), and the quality of the mixing of air (oxygen) and emissions.

The general nature of reductions achieved with the experimental configurations tested is indicated by the plots of Figures 3-12 through 3-15. Those plots show comparative emissions and temperature versus power mode (RPM) and amount of secondary air for the three exhaust treatment approaches. Test points at 28 degrees ignition timing, A/F = 11.5 and 100 and 110% secondary air were selected as representative conditions which stay mainly within the allowed temperature band.

Referring to Figure 3-12 for THC, the baseline curve at the top was constructed by averaging the THC values measured for the three control approaches, with zero secondary air. Data are plotted for both 100% and 110% secondary air except for the 110% data point at 2750 RPM which was aborted for all three approaches because of excessive temperatures.

Reduction of THC was negligible for the secondary air system at 900 and 1100 RPM because the exhaust gas temperature entering the system was inadequate to start an effective combustion process. The better thermal and aerodynamic properties of the thermal reactor (e.g., insulation and baffling) allow some combustion of exhaust gas to be initiated even at the low power modes, as evidenced by the slight reduction in THC at the 1100 RPM case. A major asset of a catalyst is clearly

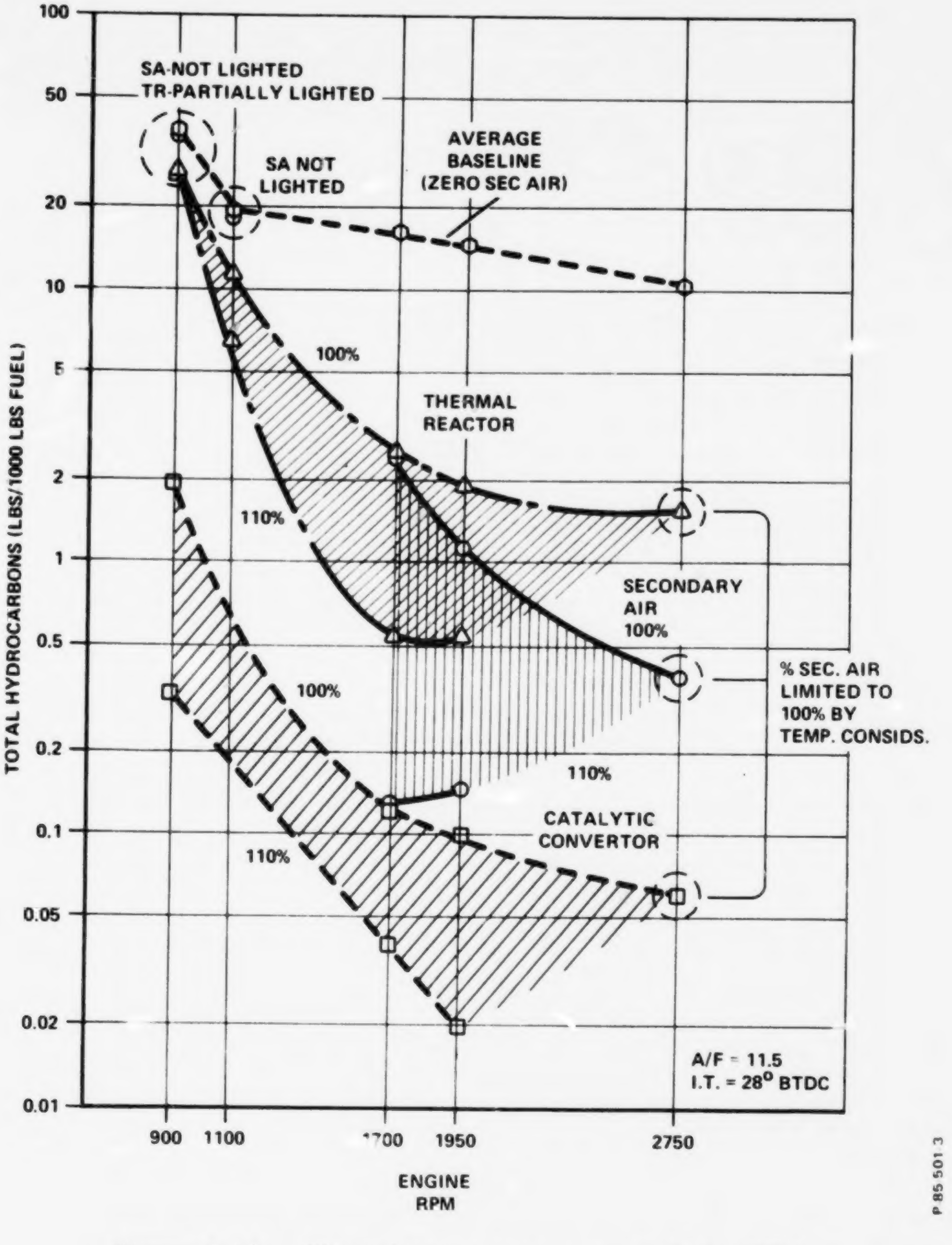

Figure 3-12 - THC Reduction versus Power Mode (RPM)

shown in that THC is reduced by factors of 20 and 100 for 100% and 110% secondary air even at the low-temperature case at 900 RPM (3.5% of rated power).

The general superiority of the catalytic approach in reducing hydrocarbons is well illustrated in Figure 3-12, where THC is reduced by almost three orders of magnitude for the approach-power case (1950 RPM, 35% rated power) with 110% secondary air. The measured THC concentration level represented by that point was rapidly approaching the noise level for those measurements, indicating essentially total effective THC elimination at that condition. The experimental thermal reactor system achieves a reduction factor of 30 at the same load condition, and the experimental secondary air system as implemented provides a reduction of 100 at the 1950 RPM case with 110% secondary air.

The curves for the 100% and 110% secondary air for the three control approaches are joined by cross-hatching for enhanced visual presentation. The rise in the lower level of the envelopes' shading between 1950 and 2750 RPM is not caused by a decreased effectivity of the approaches as such but reflects the fact that full 110% secondary air could not be attained at that power level because of temperature constraints. Had the secondary air level been increased gradually from 100% until the maximum limiting temperature was reached, somewhat better reduction than indicated might have been achieved at the 2750 RPM case.

The relative effectivity of the control approaches in reducing CO is illustrated in Figure 3-13. As with the THC plot of Figure 3-12, the baseline curve is based on the averages of CO measured at the zero air case for all three systems. The relative independence of CO formation on power level (lbs CO/1000 lbs of fuel) is clearly shown by the flat baseline plot.

As with THC, negligible reduction is achieved by straight secondary-air injection at the 900 and 1100 power points because of inadequate exhaust gas temperature. Some noticeable but small reduction is initiated in the thermal reactor for those points. After definite light-off is achieved in the secondary air and thermal reactor systems their performance is roughly equivalent, with slightly better reduction achieved by the secondary air approach.

Performance of the catalytic convertor is again, generally, the best of the three, with about a factor of five reduction in CO for all power modes at 100% air injection and an order of magnitude better (factor of 50) reduction resulting with 110% air. The most significant advantage of the catalytic approach again is at the low power modes (900 and 1100 RPM) where the catalytic convertors initiate light-off of the exhaust products so that reduction of CO is as good or better at idle as it is at the higher power modes representing approach, takeoff and climbout. Measurements at 2750 RPM and 110% air were deleted because of excessive temperature buildup. The catalyst temperature reached approximately 1600°F for the 2750 RPM, 100% air case, indicating that

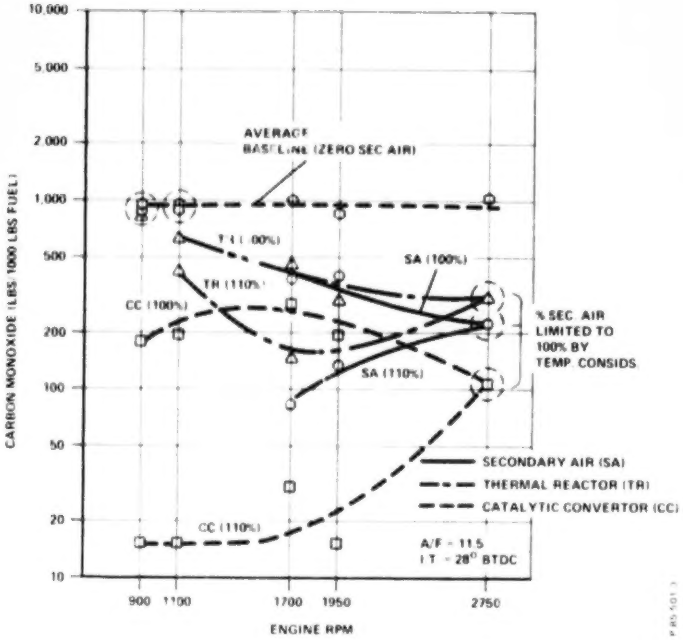

Figure 3-13 - CO Reduction versus Power Mode (RPM)

the factor of ten reduction achieved was the best achievable within the temperature limits of the test system.

The effect of exhaust treatment on NO_x emissions is shown in Figure 3-14. The major effect notable is that, in general, the secondary air and thermal reactor systems have only a small effect relative to the normal baseline rise of NO_x with power which results from increased combustion temperature. The behavior of the catalytic convertor is essentially the same as the other systems with 100% secondary air. However, the behavior of the catalytic convertor for 110% secondary air is unusual in that a substantial reduction of NO_x is indicated for the 110% cases at the 900, 1700 and 1950 RPM cases. A check of catalyst behavior at similar points with ignition timing of 23° also indicates some reduced values of NO_x relative to the 23° baseline.

The general temperature conditions that existed for the baseline and 100% and 110% secondary-air cases described above are shown in Figure 3-15. The secondary-air temperature was measured by a probe in the exhaust gas flow just downstream of the left standard heat muff, and the values are lower than the actual exhaust port temperatures experienced. The thermal reactor temperatures were measured by a probe inserted directly into the center core of the reactors and more closely indicate the maximum initial exhaust gas temperature. The catalytic convertor temperatures were measured by a probe inserted in the gas flow within the convertor envelopes just downstream of the catalyst cores.

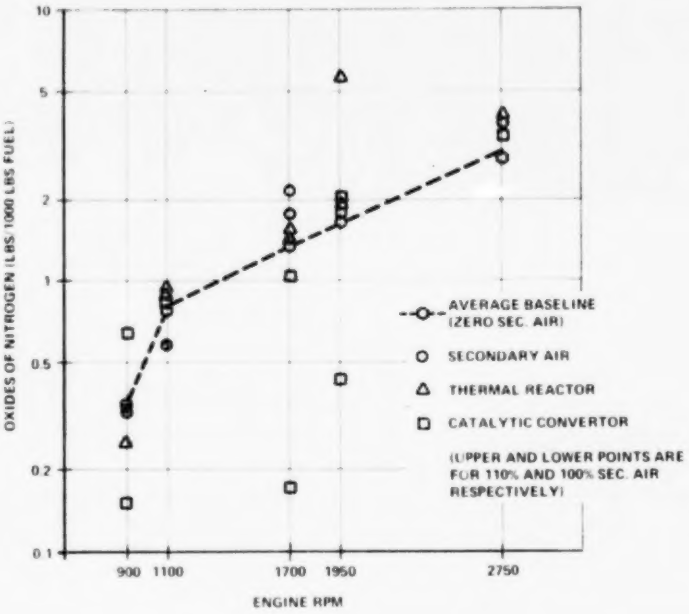

Figure 3-14 - NO_x Effect versus Power Mode (RPM)

As indicated by the baseline curves for zero secondary air, the temperatures in the secondary air system and the catalytic convertors are significantly lower than in the thermal reactors. This is as expected in that the thermal reactor temperature is measured closer to the exhaust-ports, and the thermal reactors are designed and insulated to provide a high-temperature mixture region for reaction of the exhaust gas and injected air.

As 100% secondary air is injected, the catalytic system immediately starts combusting even at low power levels as indicated by the temperature increase from 500°F to 1080°F at 900 RPM. The deficient combustion performance of the secondary air and thermal reactor systems at low power is shown by the lack of increased temperature at 900 RPM. The straight secondary air system, in fact, follows the baseline (zero air) curve until the 1700 RPM point, where exhaust gas temperature is adequate to initiate some measurable combustion. The thermal reactor temperatures start departing from the baseline at the 1100 RPM case, indicating significant combustion has been initiated.

Comments

The relative performance of the straight secondary injection and thermal reaction approaches are somewhat unexpected in that the simple secondary air injection system attains reductions comparable to the catalytic convertor under conditions of 10° ignition retardation.

The emissions levels achieved with the thermal reactors are generally higher (less reduction) than those with secondary air alone, but the spread with retarded ignition timing is less. Referring to Figure 3-12, the thermal reactor and catalytic convertor approaches put a boundary on the performance achieved with the exhaust treatment systems tested. The secondary air approach varies in performance between those bounds depending upon ignition timing.

A probable explanation for this behavior is in the detailed designs of the experimental test configurations. As indicated in Section 2.4, to facilitate the measurement of exhaust emissions, the tubing from the standard heat muffs were extended and joined in a "T" approximately two feet downstream from the heat muffs. Such an elongation of the standard exhaust system actually represents a form of thermal reactor design in that the mixing and residence times of the exhaust and secondary air were significantly increased compared to the standard configuration, which normally vents to atmosphere a short distance beyond each heat muff. This allowed a much better combustion process to take place, with subsequent better reduction of emissions than ordinarily should have resulted with secondary air injection. For this configuration, light-off was definitely enhanced by retarded ignition timing, and excellent combustion of the gases was possible (approaching the catalytic convertors) because of the long path and gradual burning process.

In the thermal reactor design, the heat muffs were replaced with the reactors, and secondary air was introduced by injectors passing through the reactors into the exhaust ports parallel to the exhaust flow. As with the secondary injection approach, the outputs of the reactors were joined at a "T" and exhaust gas was sampled in the common path beyond the "T".

Considering the two configurations and their detailed differences, it appears that the gradual mixing and combustion in the plain long exhaust tubing was potentially superior to the more rapid turbulent mixing attempted in the thermal reactors. The temperatures reached in the thermal reactor core were higher than those measured in the exhaust system downstream of the heat muff. (Figure 3-15). It is possible that the rapid combustion which presumably took place in the reactors resulted in an exhaust composition which did not utilize the residence time in the tubing as effectively as in the secondary air system.

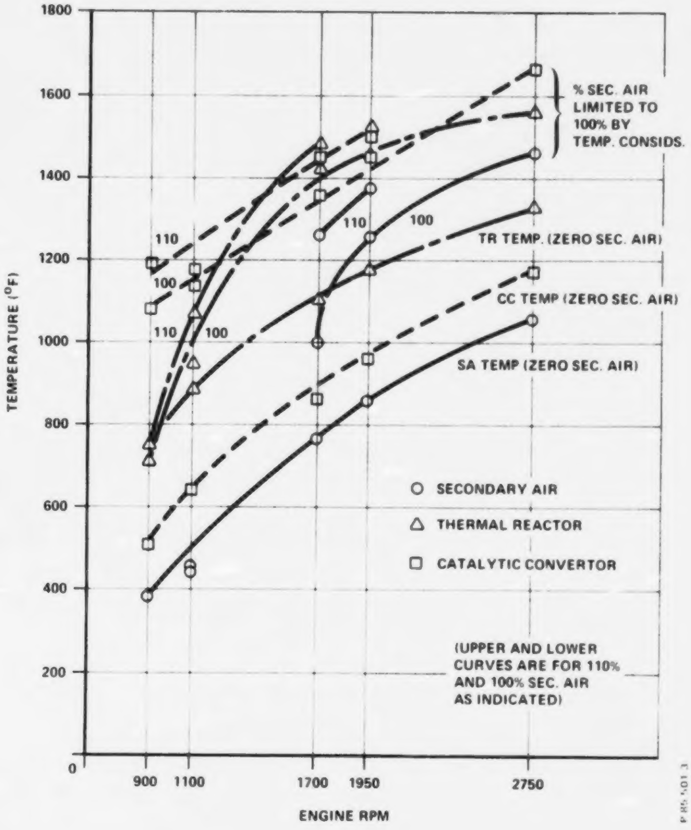

Figure 3-15 - Temperature versus Power Mode (RPM)

3.3 LYCOMING IO-540 EVALUATION

The Lycoming test series included the measurement of exhaust emissions and various engine and system temperatures at idle, takeoff, climbout, and approach conditions (1) over an engine variables matrix consisting of three variations in air-fuel ratio and ignition timing and (2) with crankcase gas returned to the intake manifold (PCV). Evaluation of exhaust treatment systems was limited to a preliminary investigation of the turbocharger as a secondary-air source because of operational difficulties of the turbocharger application described in Section 3.3.3 below.

3.3.1 Effect of Engine Variables

Baseline data were recorded for steady-state operating conditions with nominal air-fuel ratios of 10.1:1, 11.5:1 and 13.0:1

and ignition timing of 25° (factory setting), 20°, and 15° BTDC. The following load rpm and torque conditions were used:

Mode Represented	Engine Speed (RPM)	Brake Torque (ft-lbs)	Power (BHP)	Power (% Rated)
Idle/Taxi (Out)	1000	70	13.3	5.1
Takeoff	2700	410 (WOT)	210.8	81.1
Climbout	2400	400	182.8	70.2
Approach	1900	250	90.5	34.8
Idle/Taxi (In)	1000	70	13.3	5.1

With the magneto set to the desired value and the engine warmed up, the engine was set to the desired speed, torque and air-fuel ratio. Sampling of exhaust gas composition was started after the operating conditions were stabilized. The air-fuel ratio was varied at each engine speed as required by the test matrix.

The basic engine variables test matrix was as follows:

Ignition Timing	Power Setting (RPM)	Air-Fuel Ratio	PCV Status
25°	1900	10, 11.5, 13	Without and With PCV
25°	1000	10, 11.5, 13	Without and With PCV
25°	2400	10, 11.5, 13	Without and With PCV
25°	(1900)	(11.5)	Without PCV (Repeat Point)
25°	2700	10, 11.5, 13	Without PCV
25°	(1900)	(11.5)	Without PCV (Repeat Point)
25°	(2700)	(10)	Without PCV (Repeat Point)
25°	(1000)	(10)	Without PCV (Repeat Point)
20°	1900	10, 11.5, 13	PCV at A/F = 11.5 only
20°	1000	10, 11.5, 13	PCV at A/F = 11.5 only
20°	2400	10, 11.5, 13	PCV at A/F = 11.5 only
15°	1900	10, 11.5, 13	PCV at A/F = 11.5 only
15°	1000	10, 11.5, 13	PCV at A/F = 11.5 only
15°	2400	10, 11.5, 13	PCV at A/F = 11.5 only

The 2700 RPM power points were deleted from the 20° and 15° timing runs to minimize engine operating time at higher cylinder-head temperatures.

As discussed later in this section, selected points at low RPM were rerun to recheck emissions with retarded ignition timing after cleaning the spark plugs. Conditions rechecked were:

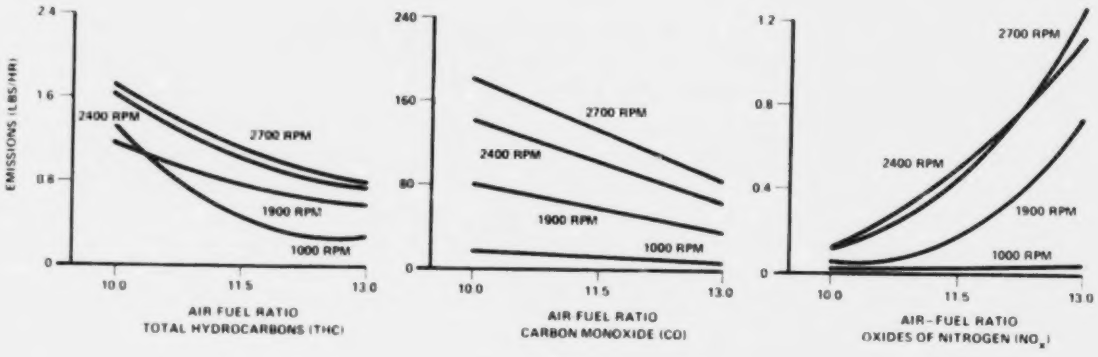

Figure 3-16 - Emissions versus Air-Fuel Ratio - Lycoming IO-540 Engine

Ignition Timing	Power Setting (RPM)	Air-Fuel Ratio	PCV Status
25°, 20°, 15°	1900	11.5	No PCV
25°, 20°, 15°	1000	10, 11.5, 13.0	No PCV

Results

Data and computed emissions values are presented in Appendix C.

Air-Fuel Ratio Variation

The effects of air-fuel ratio on engine emissions, temperatures, and brake specific fuel consumption are summarized in Figures 3-16, 3-17 and 3-18, respectively.

The general shape and magnitudes of the emissions curves of Figure 3-16 are consistent with known general characteristics for piston engines operating below stoichiometric ratios as shown in Figure 2-1. The total hydrocarbons increase with richer air-fuel ratios and are essentially proportional to rpm on a lbs/hour basis, except that at 1000 rpm and rich (10 to 1) air-fuel ratio, the THC was larger than at 1900 rpm. Some roughness at 1000 rpm idle was experienced occasionally during runs at 10:1 air-fuel ratio, which probably accounts for the high value of THC for that case. It is believed that the rich limit of ignition was beginning to take place in the form of very slow flame propagation rates and occasional misfire. CO versus A/F is linear and inversely proportional to A/F, as expected. NO_x rises rapidly with increased air-fuel ratio except for the low-power idle condition, where the combustion temperatures required for significant NO_x formation were not attained.

Plots of average cylinder head temperature (CHT) and exhaust gas temperature (EGT) as functions of air-fuel ratio (A/F) for the various power modes are shown in Figure 3-17.

Figure 3-18 indicates the variation in brake specific fuel consumption at various rpms and air-fuel ratios. The curves indicate reduced BSFC with increasing air-fuel ratio and rpm, which is typical piston engine performance in the air-fuel ratio range observed. Shown on the plot are two values of BSFC as calculated from the manufacturer's manual for 2400 rpm best economy and best power mixture settings. The intersection of the 2400 RPM line, if extrapolated, crosses those lines at about 15 to 1 and 13 to 1, which is close to the normal piston engine characteristics.

The effect of ignition timing on the exhaust emission products is shown in Figure 3-19. The effect of ignition timing is somewhat random except that retarded ignition timing seems to cause a slight increase in THC at A/F = 10 while the leaner air-fuel ratios are essentially unaffected by retarded timing. CO increases slightly with retarded timing for the richer, higher power cases. The curves of NO_x generation show the reduced NO_x output with retarded timing which results from the reduction of the peak cylinder temperatures. Similarly, the NO_x formation at 1000 RPM is reduced, essentially to an insignificant amount, because the peak cycle temperature is very low.

The effect of ignition timing on cylinder head and exhaust gas temperature is shown in Figure 3-20. As expected, retarded timing increases EGT for all observed RPM's. The cylinder head temperatures remain essentially constant at low RPM, and there is a slight reduction with retarded timing at high (2400) RPM.

Retarding ignition timing from the manufacturer's recommended setting produces an increase in brake specific fuel consumption for all observed RPM's as shown in Figure 3-21.

During the course of the testing, low-speed, rich operation test points were generally alternated with high-power runs to minimize spark plug fouling. When the THC data at 1000 RPM, A/F = 10 and 11.5, showed a significant increase with retarded timing (Runs 21 and 30) the test conditions were reviewed.

Since some engine roughness had been noted at rich, retard conditions, the spark plugs were inspected, gap checked and pressure tested. No apparent discrepancies were found, but the plugs were sand blasted without any other change and the engine was retested. The results of cleaning the spark plugs with a standard sand blast unit are shown in Figure 3-22. The subsequent change in THC is shown by the curves for the freshly cleaned spark plugs. Apparently ignition of the charge was close to being marginal at rich, idle conditions with in-use spark plugs and the slight plug degradation during the test series showed up in the THC measurement. The spark plugs were delivered with the engine and were

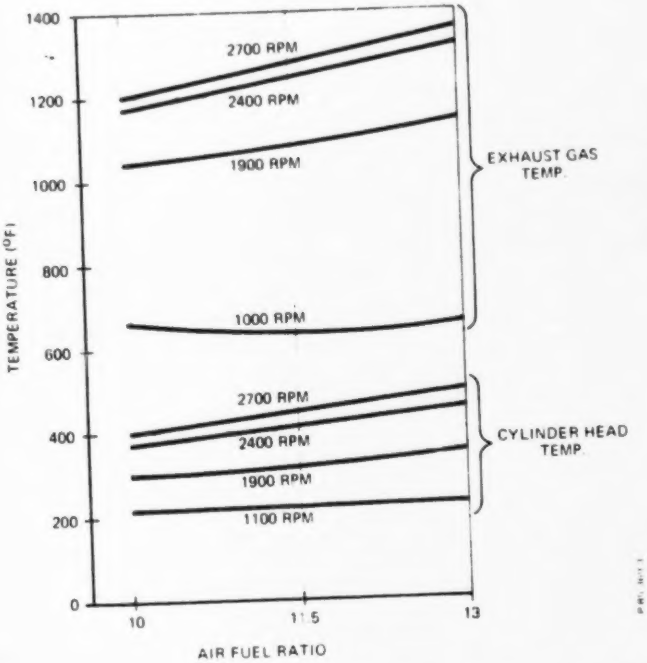

Figure 3-17 - Temperature versus Air-Fuel Ratio - Lycoming IO-540 Engine

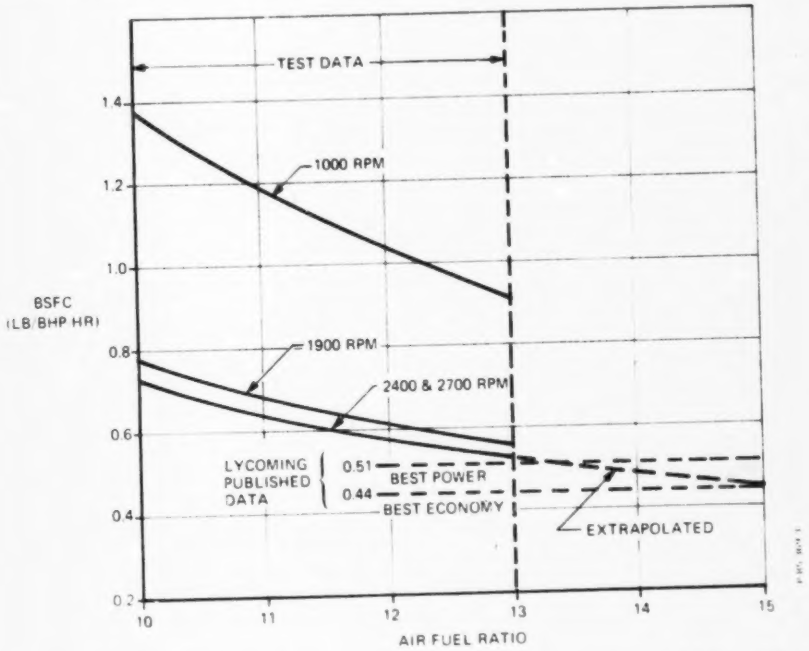

Figure 3-18 - Brake Specific Fuel Consumption versus Air-Fuel Ratio - Lycoming IO-540 Engine

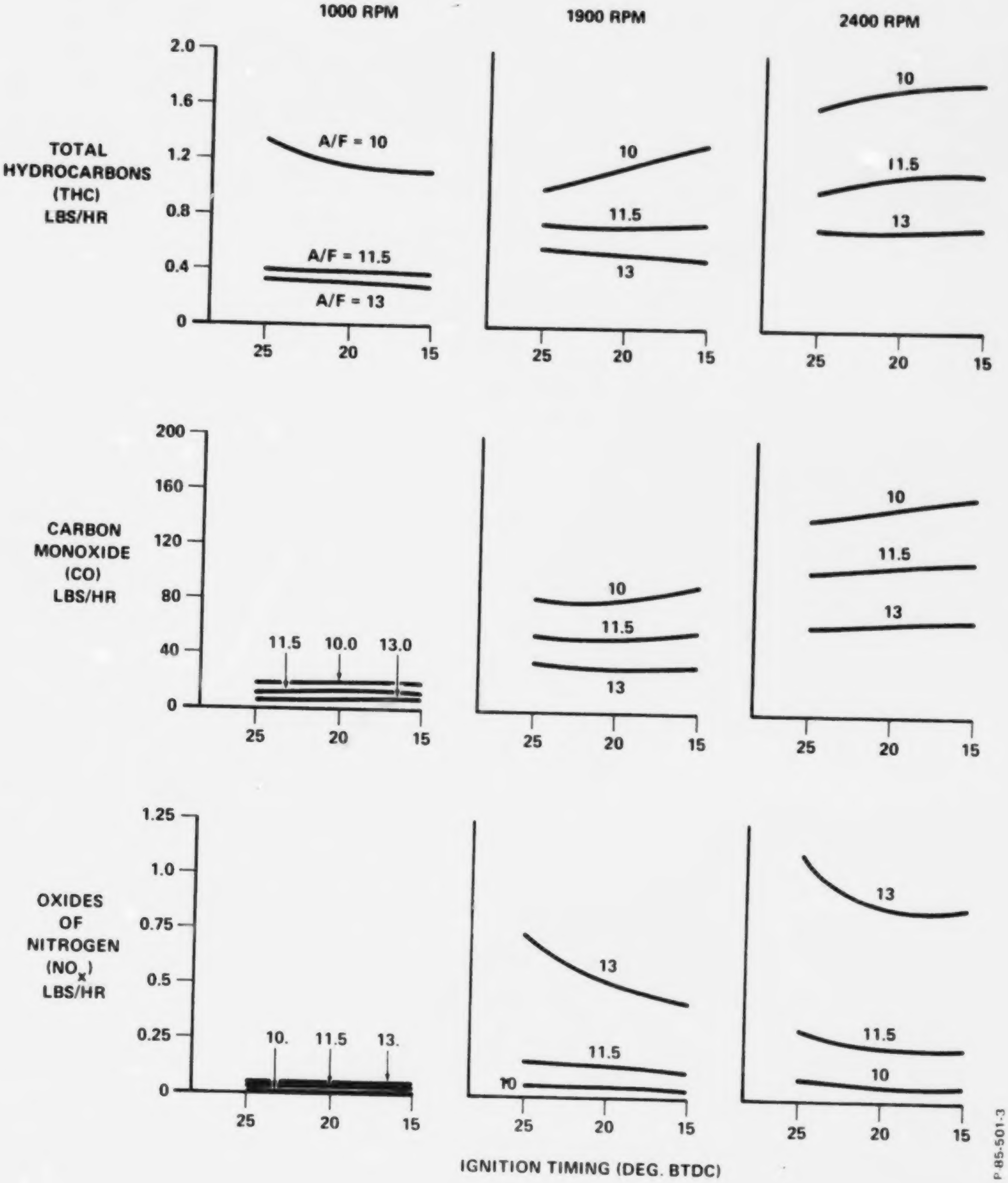

Figure 3-19 - Emissions versus Ignition Timing - Lycoming IO-540 Engine

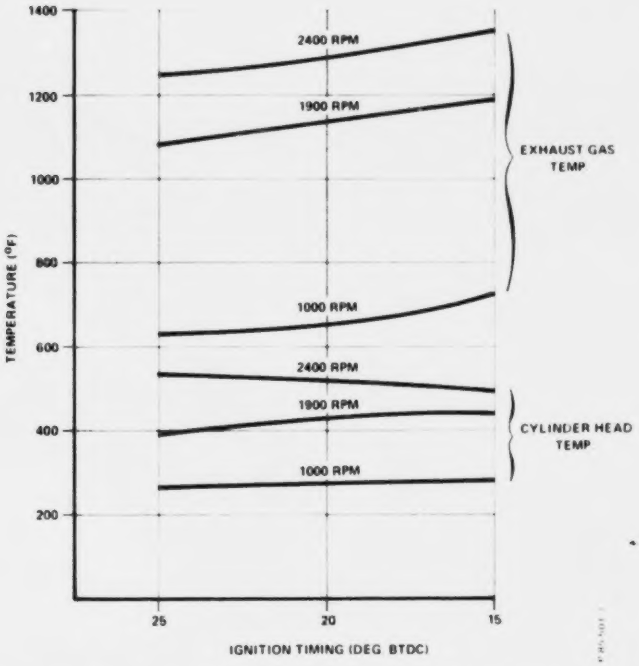

Figure 3-20 - Temperature versus Ignition Timing - Lycoming IO-540 Engine

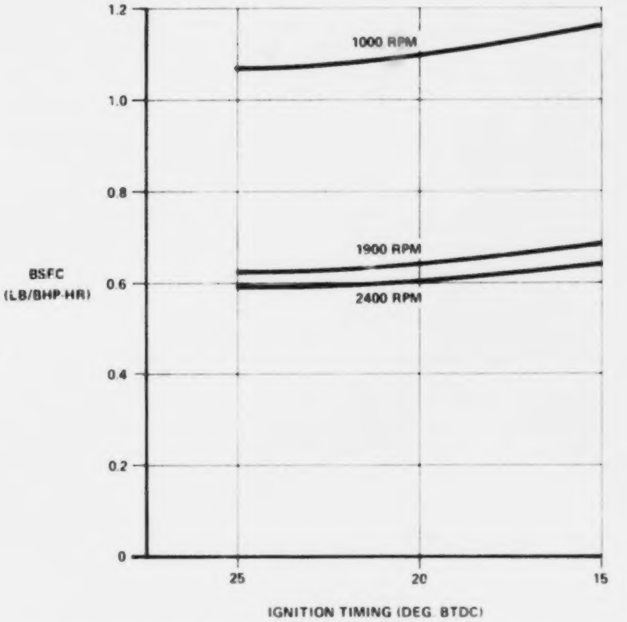

Figure 3-21 - Brake Specific Fuel Consumption versus Ignition Timing - Lycoming IO-540 Engine

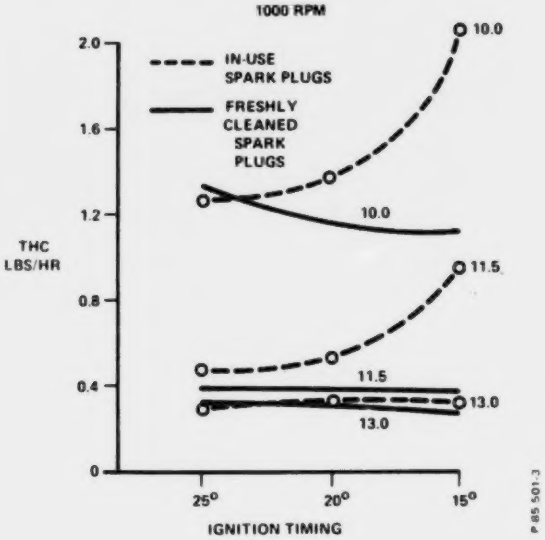

Figure 3-22 - Effect of Retarded Timing and Degraded Spark Plug Conditions

Table 3-2 - Effect of PCV on Emissions - Lycoming IO-540 Engine

ENGINE CONDITION		W/o PCV		W/PCV		PERCENT CHANGE IN THC w/PCV (EXHAUST GAS)	(PERCENT CONTRIBUTION OF CRANKCASE TO TOTAL EMISSIONS*	APPROXIMATE NET CHANGE IN TOTAL THC w/PCV
RPM	A/F	THC (PPM)	MAP IN Hg	THC (PPM)	MAP IN Hg			
1000	10	14,882	13.2	16,173	13.4	+8.6	≈ +5 (IDLE TAXI)	+4
	11.5	6,104	12.8	5,984	12.9	-2.0		-7
	13	3,808	12.2	3,637	12.2	-4.7		-10
1900	10	3,551	19.7	3,472	20.1	-2.2	+24.6 (APPROACH)	-27
	11.5	2,690	19.1	2,736	19.4	+1.7		-23
	13	2,037	19.7	2,023	19.9	-0.6		-25
2400	10	3,248	24.5	3,107	25.8	-4.5	≈ +22 (TAKE OFF CLIMB)	-26
	11.5	1,987	25.7	1,995	25.9	+0.4		22
	13	1,477	25.4	1,390	25.9	-6.2		-28
2700	10	2,802	26.6	2,867	26.6	+2.3		20
	11.5	1,934	26.6	2,032	26.6	+5.0		17
	13	1,300	26.6	1,383	26.6	+6.0		16

*BASED ON DATA FROM "FINAL REPORT A STUDY OF AIRCRAFT POWERPLANT EMISSIONS", SCOTT RESEARCH LABORATORIES INC. (2)

unused at the beginning of the test series. They had less than 20 hours total usage at the time of sand blasting. The data plots of Figure 3-19 incorporate the rechecked data with cleaned plugs for best presentation of the general effect of ignition timing variation. Data from the recheck runs are presented in Appendix C-2.

3.3.2 Effect of PCV

The effect of returning crankcase gases to the intake manifold is summarized in Table 3-2. Data points were taken similar to those for the Continental 0-200 engine (Section 3.2.2) and are identified in Appendix C-1 with the suffix "P".) The effects on both exhaust THC emissions and on manifold absolute pressure (MAP) tend to be slight (< ±10% for THC; < +2% for MAP). The 1-2% increase in MAP is consistent with the general magnitude of crankcase gas flow introduced relative to induction air flow. The changes in exhaust THC tend to vary somewhat randomly, and undoubtedly include some component of measurement inaccuracy. Changes in engine torque noted (Appendix C-1) also vary and are small enough to be subject to minor changes in test conditions during the PCV tests.

The crankcase gases can affect the actual air-fuel ratio of the cylinder depending upon the constituents of the crankcase gases. In general the crankcase gases will be a fuel-rich mixture plus inert components. Thus, a slight richening tendency should occur in the engine cylinder. The data suggests that the tendency is small. The greatest effect of PCV is the elimination of the direct dumping of crankcase gases to the atmosphere. The estimated reduction in total engine THC emissions is shown in the last column of Table 3-2. These data are based on information by Scott as indicated in reference .

3.3.3 Effect of Exhaust Treatment Systems

Test Setup

Implementation of the experimental exhaust treatment systems on the Lycoming IO-540 engine is described in Section 2.4.3.2 above. A photograph of the basic test assembly is shown in Figure 3-23. The thermal reactor, secondary-air manifolding, and turbocharger assembly are indicated.

Results

Preliminary tests using the turbocharger for secondary air injection in the test configuration demonstrated that a significantly modified and/or more sophisticated system configuration is required to utilize a turbocharger as a practical secondary-air source. In particular if the turbocharger is downstream of the reactor system as desired to utilize the exhaust gas combustion energy for turbocharger power, a "bootstrap" effect occurs on light-off which leads to difficulty in controlling the secondary air to prescribed safe levels with a manually controlled test configuration.

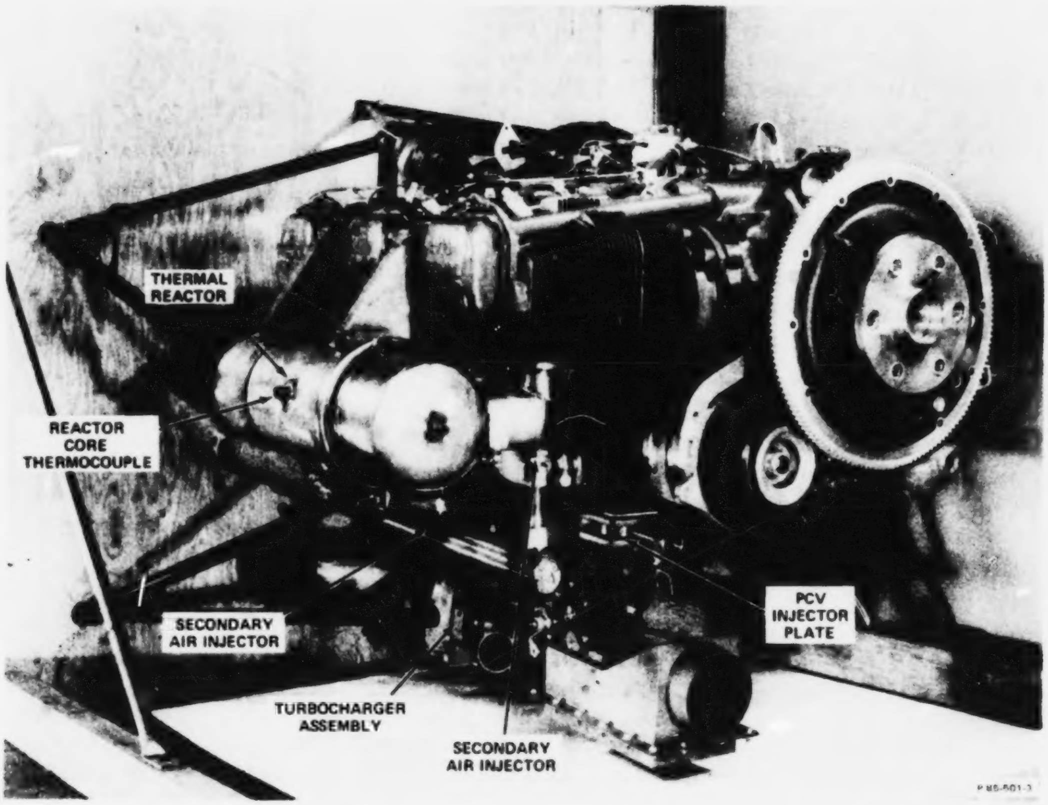
THERMAL REACTOR
REACTOR CORE THERMOCOUPLE
SECONDARY AIR INJECTOR
TURBOCHARGER ASSEMBLY
SECONDARY AIR INJECTOR
PCV INJECTOR PLATE

Figure 3-23 - Basic Test Assembly - Lycoming IO-540 Engine

For example, in tests performed at 1900 RPM (approach power) it was found that as the secondary air was increased to light-off level, a rapid (less than one second) increase in turbocharger output pressure and flow resulted when light-off occurred. This resulted in a consequent rapid increase in exhaust gas temperature to beyond safe limits for both the exhaust system and the turbocharger turbine. The rise occurred too fast to allow manually controlled reduction of turbocharger input power or output air to safe levels before the test condition had to be abruptly terminated as temperatures approached 2000°F. Since the initial exhaust gas temperatures are higher for the 2400 RPM (climbout) and 2700 RPM (takeoff) power settings (and with retarded ignition timings), a similar temperature problem can be expected at those conditions.

The exploratory tests also demonstrated that the turbocharger selected does not derive sufficient input power at 1000 RPM (idle) to provide the required secondary air levels, and testing of exhaust treatment systems therefore cannot be run at those conditions with the existing turbocharger.

This experience does not imply that turbochargers are not usable as secondary-air sources in piston engine aircraft but that their use requires analysis and design sophistication beyond the scope of the current contract effort.

The bootstrap effect noted can be eliminated if the turbocharger is inserted close to the exhaust ports and the reactor is downstream of the turbine. Turbocharger flow (used for secondary air) would be injected at the reactor input, downstream of the turbine, and no positive feedback effect would occur at light-off. This would, of course, result in lower temperature gases available at the reactor input because of drop through the turbine and would limit the secondary-air use to high-power cases only and/or with catalytic convertors.

The limiting of turbocharger use to high power modes because of power range limits of the turbocharger turbine itself or because of the temperature considerations just discussed would tend to restrict the secondary air to flight modes of the LTO cycle. Since the climbout and approach modes are major sources of emissions within the LTO cycle because of their power levels and durations, restriction of exhaust treatment to those modes might still be adequate to meet the standards ultimately adopted.

SECTION 4

FEASIBILITY AND IMPLEMENTATION CONSIDERATIONS

4.1 GENERAL SCOPE OF EVALUATION

The objective of this section is to compare the relative performance of the various automotive-type emission control systems in light of the special requirements of the aircraft engine. In addition, the test results of the program are compared against the proposed Federal standards as published in December, 1972. Some conclusions are drawn as to the effectiveness of the various emission control systems tested in meeting the proposed standards.

The feasibility of applying such equipment and concepts to flightworthy systems is also discussed. Problem areas and areas requiring further investigation and development are delineated and comments on the safety and economic considerations are given where possible.

4.2 COMPARATIVE PERFORMANCE EVALUATION OF CONTROL APPROACHES

Emission control techniques and systems selected as potentially appropriate for aircraft piston engine application were (1) variation of air-fuel ratio and ignition timing; (2) exhaust treatment by air injection, thermal reaction, and catalytic conversion; and (3) return of crankcase gases to the intake manifold (positive crankcase ventilation).

Positive Crankcase Ventilation

Positive crankcase ventilation (PCV) is a special case in that it totally eliminates a significant source of hydrocarbon emissions (up to 25% of the total) with relatively little effect on engine performance. The major concerns with PCV for aircraft are in the practical considerations of implementation, as discussed in Section 4.3 below.

Exhaust Emissions Control

The proposed standards for exhaust emissions as published in December 1972[1] are stated in terms of pounds/rated horsepower/cycle so that larger engines are allotted a proportionally larger emissions allowance than smaller engines. The proposed standards as applied to the Continental 0-200 and Lycoming IO-540 engines are as shown in Table 4-1.

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[1] Subpart F, para. 87.50, p. 26491.

Table 4-1 - Proposed Emissions Allowance for Continental 0-200 and Lycoming IO-540 Engines

POLLUTANT	PROPOSED FEDERAL STANDARD (LB/RATED HP/CYCLE)	CONT. 0-200 (100 HP) (LB/CYCLE)	LYC. IO-540 (260 HP) (LB/CYCLE)
THC	0.00190	0.190	0.494
CO	0.042	4.2	10.92
NO_x	0.0015	0.15	0.39

The LTO (landing-takeoff) cycle applicable to engines of this class (Class P1), and the nominal power conditions used for the test and evaluation series, are shown in Table 4-2. The values used for the tests were derived before the proposed Federal standards were published and were based primarily on an assumed cubic propeller loading curve referenced to 100% power at the manufacturer's recommended maximum RPM (at takeoff). The engine RPM values for the various modes were selected from typical airframe operation manuals for aircraft using the engines selected for this test program.

Power levels for takeoff and/or climbout test conditions were established by actual power achieved with wide open throttle (WOT) for the Continental 0-200 engine and as indicated for the Lycoming IO-540 engine. The actual power levels achieved at takeoff rpm are 15 to 20% below the specified 100%, but this has only a slight effect on cycle emissions calculated below because of the short duration of the takeoff mode. The emissions measured could be corrected to match more closely the specified power levels by extrapolation if desired.

To indicate the general emissions performance of the two engines tested, relative to the proposed standards, a set of nominal air-fuel ratios was selected as follows:

Mode	Air-Fuel Ratio
Idle/Taxi (out)	10
Takeoff	11.5
Climbout	11.5
Approach	11.5
Idle/Taxi (In)	10

Table 4-2 - Modal Powers and Durations

PROPOSED FEDERAL STANDARDS (DEC. 1972)			POWER USED FOR TEST SERIES	
LTO CYCLE MODES	DURATION (MIN.)	SPECIFIED POWER FOR TEST	CONT. 0-200	LYCOMING IO-540
TAXI/IDLE (OUT)	12.0	MFGR'S RECOMMENDED POWER SETTING	3.5% (900 RPM)	5.1% (1000 RPM)
TAKEOFF	0.3	100%	86.5% (WOT) (2750 RPM)	81.1% (WOT) (2700 RPM)
CLIMBOUT	5.0	75 - 100%	86.5% (WOT) (2750 RPM)	70.2% (2400 RPM)
APPROACH	6.0	40%	35.7% (1950 RPM)	34.8% (1900 RPM)
TAXI/IDLE (IN)	4.0	MFGR'S RECOMMENDED POWER SETTING	6.4% (1100 RPM)	5.1% (1000 RPM)

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Using these assumed values for air-fuel ratio, the cycle emissions for the two engines were calculated from average emissions data measured. Factory ignition timings of 28° BTDC and 25° BTDC were used for the Continental 0-200 and Lycoming IO-540 engines respectively. Mass emissions derived for the two engines are shown in Tables 4-3 and 4-4.

As indicated at the bottom line of the tables, as tested and for the air-fuel ratios assumed, both engines were within approximately 25% of the THC standard, were a factor of two over the CO standard, and were approximately an order of magnitude below the NO_x standard.

For both engines, with the air-fuel ratios assumed, the combined idle/taxi modes produce more THC than the combined climbout and approach modes by a factor of approximately 1.5 to 2. The climbout mode is the largest contributor of CO, producing approximately twice the amounts of the taxi/idle and approach modes. The NO_x generated in the total cycle is sufficiently low not to be of concern. For both engines, the mass emissions at takeoff are negligible because of the very short duration of that mode (0.3 minute) relative to the total cycle (1.1%).

The emissions can be modified to fall under the proposed standard values by increasing air-fuel ratio or by the application of exhaust treatment systems. A wide variety of air-fuel ratio and ignition timing combinations can be assumed to the various modes if only those engine parameters are varied. The situation becomes even more complex for exhaust treatment systems in that the amount of secondary air is also a variable.

To give a general indication of conditions which result in acceptable emissions levels, several air-fuel ratio combinations were developed which give suitably reduced emissions. An example is also given for each

Table 4-3 - Nominal Modal Emissions from Continental 0-200 Engine

MODE	RPM	A/F	TIME (MIN.)	EMISSIONS (LBS/MODE)		
				THC	CO	NOx
IDLE/TAXI (OUT)	900	10.0	12.0	0.116	1.38	0.0002
TAKEOFF	2750	11.5	0.3	0.003	0.26	0.0009
CLIMBOUT	2750	11.5	5.0	0.048	4.32	0.0154
APPROACH	1950	11.5	6.0	0.039	2.24	0.0043
TAXI/IDLE (IN)	1100	10.0	4.0	0.033	0.62	0.0001
	EMISSIONS (LBS/CYCLE)			0.239	8.82	0.0209
	PROP. FED. STD. (12/72)			0.190	4.2	0.150
	% OF P.F.S. (12/72)			126	210	14

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Table 4-4 - Nominal Modal Emissions from Lycoming IO-540 Engine

MODE	RPM	A/F	TIME (MIN.)	EMISSIONS (LBS/MODE)		
				THC	CO	NOx
IDLE/TAXI (OUT)	1000	10.0	12.0	0.254	4.14	0.0001
TAKEOFF	2700	11.5	0.3	0.006	0.67	0.0014
CLIMBOUT	2400	11.5	5.0	0.085	8.71	0.0267
APPROACH	1900	11.5	6.0	0.075	5.65	0.0163
TAXI/IDLE (IN)	1000	10.0	4.0	0.085	1.38	0.0000
	EMISSIONS (LB/CYCLE)			0.505	20.55	0.044
	PROP. FED STD. (12/72)			0.494	10.92	0.39
	% OF P.F.S. (12/72)			102	188	11

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of the three exhaust treatment approaches. Because of its demonstrated slight effect on emissions performance, ignition timing was left at the factory settings for all cases treated.

The conditions assumed and the resultant emissions are presented in Table 4-5. The effect of varying air-fuel ratio is considered for various mode combinations in cases 1-4 and 8-11 for the Continental 0-200 and Lycoming IO-540 engines, respectively. An example showing reduction achieved for 100% secondary air is given for each of the three exhaust treatment approaches used with the Continental 0-200 engine (Cases 5-7).

Table 4-5 - Cycle Emissions with Various A/F and Exhaust Treatment Conditions

CASE	CONDITION	A/F OR % SEC. AIR PER MODE (ASSUMED OR DERIVED)					CYCLE EMISSIONS (% PROP. FED. STD.)		
		IDLE/ TAXI (OUT)	TAKEOFF	CLIMBOUT	APPROACH	IDLE/ TAXI (IN)	THC	CO	NO_x
	CONTINENTAL O-200 VARIOUS A/F @ 28° I.T.								
(1)	NOMINAL A/F (A/F)	10	11.5	11.5	11.5	10	126	210	14
(2)	ALL MODES UNIFORMLY LEANED (A/F)	13.4	13.4	13.4	13.4	13.4	25	100	50
(3)	ALL MODES LEANED EXCEPT T.O. (TAKEOFF @ 11.0) (A/F)	13.5	11.0	13.5	13.5	13.5	26	98	55
(4)	TAKEOFF @ 11.0; CLIMBOUT A/F CALCULATED W/OTHER MODES @ STOICHIOMETRIC (≈14.7) (A/F)	STOICH	11.0	12.4	STOICH	STOICH	47	100	52
	EXHAUST TREATMENT SYSTEMS								
(5)	SECONDARY AIR INJECTION ALL MODES @ A/F = 11.5 (% SEC. AIR)	0	100	100	100	0	33	73	16
(6)	THERMAL REACTOR ALL MODES @ A/F = 11.5 (% SEC. AIR)	0	100	100	100	0	36	88	23
(7)	CATALYTIC CONVERTOR ALL MODES @ A/F = 11.5 (% SEC. AIR)	100	100	100	100	100	18	29	11
	LYCOMING IO-540								
(8)	NOMINAL A/F (A/F)	10	11.5	11.5	11.5	10	102	188	11
(9)	ALL MODES UNIFORMILY LEANED (A/F)	13.2	13.2	13.2	13.2	13.2	41	96	34
(10)	ALL MODES LEANED EXCEPT T.O. (TAKEOFF @ 10.5) (A/F)	13.2	10.5	13.3	13.3	13.3	42	100	33
(11)	TAKEOFF @ 10.5; CLIMBOUT A/F CALCULATED W/OTHER MODES @ STOICHIOMETRIC (≈14.7) (A/F)	14.7	10.5	12.5	14.7	14.7	31	100	60

Cases 1 and 8 are for nominal conditions as discussed earlier, repeated here for convenient reference.

Cases 2 and 9 show the level of leanness required to meet the standards if all modes are leaned identically, resulting in air-fuel ratios of 13.4 and 13.2 for the Continental 0-200 and Lycoming IO-540 engines, respectively.

Cases 3 and 10 show the level to which all other modes must be leaned if the takeoff mode is left at the nominal baseline values. Because of the very short takeoff mode duration (0.3 minute), the increase in other-mode uniform air-fuel ratios is only approximately 0.1 air-fuel ratio.

Cases 4 and 11 show the air-fuel ratio for the climbout mode if takeoff is left at the nominal enriched value and the taxi-idle and approach modes are leaned to the stoichiometric value (≈14.7). For such a case, the climbout mode air-fuel ratios are 12.4 and 12.5, respectively.

Cases 5-7 give a single example for each exhaust treatment system of how the proposed standard values are met with combinations of air-fuel ratio and secondary air. A wide variety of combinations of air-fuel ratios and secondary air are possible for the various modes. For simplicity, an average air-fuel ratio of 11.5 was assumed, and secondary air for 100% stoichiometric mixture at the exhaust was assumed. Since neither the secondary air or thermal reactor systems are effective at taxi/idle powers, the systems are assumed off (zero air) for those modes.

Cases 5 and 6 show that both secondary air and thermal reactor systems can provide satisfactory emission values for the conditions assumed. Since the catalytic convertor is effective at low powers, it reduces the emissions level for the taxi/idle modes and is generally more effective at the other modes as well. Case 7 indicates the improved performance of the catalytic convertor.

The above examples are meant to provide a gross numerical indication of the performance of the various approaches relative to the standard values proposed at the time of the preparation of this report. Similar calculations can be made as desired for other combinations of air-fuel ratio, ignition timing, and exhaust treatment with the data provided in Section 3 or in Appendices B and C. For the examples cited, emissions (in particular CO) were only required to be equal to or less than the standard value. Any factor applied to new engines to allow for manufacturing tolerances or aging effects between overhauls would, of course, modify the numbers shown in the examples.

4.3 CONSIDERATIONS OF PRACTICAL IMPLEMENTATION

The control of exhaust emissions from light piston-engine aircraft can be implemented by either fuel management methods or exhaust treatment systems. The contribution of crankcase gases to the total engine emissions may be controlled by capturing and readmitting crankcase gases into the engine system in various ways.

4.3.1 Fuel Management

Various specialized methods of providing the desired mixture of the fuel and air to the cylinder are known, but this study considers only the carburetor and mechanical fuel injection systems commonly used with piston engines for light aircraft.

If the fuel management system is required to provide the bulk of the required emission control, more precise control of the air-fuel ratio than heretofore tolerated may be required, and a variable air-fuel ratio schedule for different operational modes may be necessary. In addition, a particular engine/air frame combination may require one specific, programmed, air-fuel ratio control for various operational modes (e.g., taxi-out, takeoff, climbout), while the same engine in a different air frame, with different flight performance, may require a different air-fuel ratio program. Identification of the operational mode may be accomplished from several input sources. The simplest system approach would use throttle position only, while more complex systems could sense air speed, power output, flap position, gear position, altitude, etc., to determine the existing mode of operation in order to select the desired air-fuel ratio.

The trend will be toward leaner mixtures. Automatic enrichment control systems may be necessary to prevent cylinder head temperatures from exceeding predetermined levels. Detonation sensing and possibly engine roughness sensing may be required. Some method of ambient density compensation may be required to provide for airport altitude variations throughout the United States. Implied is the requirement for the best possible cylinder-to-cylinder distribution throughout the operating range.

In most aircraft, flight mode can effectively be established by throttle position. The desired air-fuel ratio would be established be experimentation to find the necessary or permissible ratios at the various flight modes which would meet the emission requirements during the LTO cycle. If the inherent throttle versus mixture characteristics of a given carburetor were not suitable, the desired fuel management performance might be accomplished by the incorporation of a simple mechanical programmer. Mixture command would be applied to the mechanical programmer which would also receive an input from the throttle control. The programmer then would command the carburetor mixture control position, and the engine would operate at the desired resultant air-fuel ratio. Such a mechanical programmer could be designed in many ways. In operation the pilot could apply a full-rich command to the mixture control, but the programmer would provide the proper mixture at all throttle positions except WOT. The pilot could lean the mixture more than the programmer allows, back to idle cut-off for example, but he could not enrichen beyond the programmer settings.

In the event that air density compensation is required, the design of a good economical ambient density compensation system may require development effort. The technical problem is the design of a mechanical system with essentially zero hysteresis and sufficient damping. This means that no sliding contact between moving members should exist. The pressure and temperature sensing elements may be combined in an aneroid concept. The size and weight of a density-compensated carburetor would be increased slightly over present uncompensated carburetors.

Fuel management for an injected engine would have essentially the same requirements as for a carbureted engine. Some mechanical fuel injection systems in present use are pressure compensated and some are density compensated. None are known to be programmed to provide a precise air-fuel ratio as a function of flight mode *per se*. Assuming that a desired air-fuel ratio program has been established for a particular fuel injected engine which will meet the requirements for exhaust gas emissions, the fuel metering controls in the injection system may be mechanically trimmed to meet the requirements. Fuel injection systems are currently supplied which can provide part throttle to WOT air-fuel ratio control to approximately ±3 percent on an engine installation. Idle air-fuel ratios are generally not controlled this well. Development effort could be required to provide density compensation throughout the full-idle to WOT range, if that becomes necessary. It is not expected that a significant change in size and weight of certain fuel injection systems would be required to provide the necessary programmed air-fuel ratio control. Unless the requirements demand better than ±3 percent accuracy of the fuel management system, implementation would appear to be more easily accomplished with a fuel injection system. As with the carbureted system, the better the accuracy required, the more effort will be required to develop a suitable system.

Cost Considerations

The cost of a fuel management system is dependent primarily on the required precision of the air-fuel ratio control. The effective air-fuel ratio at a carburetor is distorted at the cylinders because of the well-known distribution problem. Thus, a more precise carbureted system could require work by both the fuel control manufacturer and the engine manufacturer.

The cost of a mechanical fuel injection system is presently much higher than a carburetor for the same engine. However, the fuel injection system affords a more convenient means for establishing precise air-fuel ratio schedules. In addition, ambient pressure and density compensation features are available and implemented in some injection systems. Therefore, less change, if any, in a fuel injection system appears necessary to accomplish those functions, at least within accuracy levels provided at this time. The increase in cost of attaining any particular level of fuel management control would thus appear to be less for the fuel injection system than for the carbureted system.

Performance Considerations

The primary effects of fuel management control will be a small weight increase and possibly a WOT power reduction. The weight increase due directly to carburetor modifications could be in the order of a few pounds. If the engine is operated leaner than presently done, a reduction in rated power could be required to keep engine temperature within a permissible level. Any reduction in power available for takeoff and climbout is undesirable, as most light aircraft are not noted for high performance. A compensating technique may be the reduction in gross weight which could be accomplished by reduced fuel load or baggage/passenger load. Compensating improvements in cooling, where possible, or other such modifications not directly affecting available power would be preferable.

The only flight modes in which performance would be affected would be the WOT condition, or takeoff and climbout. Other modes at part throttle would be potentially unaffected. A density-compensated fuel control system would result in some reduction in fuel consumption, as would generally leaner operation during the LTD modes. Engine operation at more optimal air-fuel ratios during WOT periods, rather than excessively rich as altitude is gained, would also result in slight power gains.

The fuel injection fuel management system would apparently add little weight to the aircraft installation. The effect of varying the air-fuel ratio to the engine would be essentially the same for an injection system as for a carbureted system, with the exception that the injection system classically provides better distribution.

4.3.2 Positive Crankcase Ventilation

Positive crankcase ventilation has been used on automobile engines for several years. No PCV systems are in use on light piston-engine aircraft. Aircraft engine crankcases are classically vented by a simple tube connection at a point high on the crankcase. This tube is usually routed down and out the cooling air opening in the cowling. Thus the crankcase is vented but not ventilated and crankcase pressure is essentially the same as ambient. The crankcase gases consist of unburned fuel, lubricating oil vapor, water vapor and some products of combustion. The high content of hydrocarbons make the crankcase gases a significant proportion of the total hydrocarbon emissions released to the atmosphere by the engine.

The aircraft engine has several operating conditions which make it quite different from the automotive engine. The crankcase pressure must be maintained within a few inches of water of the ambient pressure or the various crankcase seals can be dislodged, or oil foaming and light hydrocarbon losses can occur. The low temperatures encountered by the aircraft engine can result in freezing of the water vapor in the PCV circuit. Ventilation is not normally considered necessary to prevent sludge buildup because the aircraft engine is usually run long enough and hot enough to flush the crankcase, as opposed to the automobile which is frequently not run long enough to reach full operating temperature.

Normally aspirated engines will, in general, always have a manifold pressure less than ambient. Pressure in the inlet box upstream of the throttle plate can be greater than ambient because of the ram effect during flight. Turbocharged and supercharged engines can have the intake manifold pressure greater than ambient. The only way to get the crankcase gases to flow to a higher pressure region is to provide a pump which will perform this function. Therefore, it appears that PCV systems for aircraft engines cannot utilize a single basic concept. The normally aspirated engine may use a system similar to some automotive applications, but turbocharged and supercharged engines would incorporate a pump in the PCV system. In all cases the PCV system will have to be located in such a way that the complete circuit can be heated well above 32°F to prevent ice formation caused by the high water-vapor content of the crankcase gases. Fully ventilated crankcase systems could be made to stay within the allowable pressure differential between the crankcase and ambient pressure. However, cold ambient air induction into the crankcase may be undesirable and could require some preheating.

Introduction of the crankcase gases and the ventilation air into the intake manifold would influence the actual air-fuel ratio supplied to the cylinders. Thus, a fuel management system would have to account for the effect of the PCV system on the desired air-fuel ratio at the cylinders. It may be desirable to locate the PCV valve inside the crankcase and minimize the length of the connecting tubing exposed to the cold ambient. It appears that the PCV system should be designed by the individual engine manufacturers to best integrate the PCV system with each particular engine.

Possible Approaches

The development of airworthy PCV systems for normally aspirated and turbocharged engines will require considerable developmental effort. The final systems which will emerge from the development activity may be quite different from the present automotive systems in use. The implementation methods discussed below are considered as concepts for illustration only and while they may appear feasible, it remains necessary to demonstrate by actual test that such is the case.

A normally aspirated engine might be provided with a PCV system where a conventional automotive type PCV valve sized for the application is provided between the crankcase and intake manifold. The pressure drop between the crankcase and manifold is utilized to pull the crankcase gases into the intake manifold. The PCV valve provides a two-step orifice control and check-valve function, as typically is done on automotive engines. The PCV valve inlet must be located as high as possible in the crankcase to minimize possible oil injection during various maneuvers. Prolonged negative "g's" would present a problem with the simple tube pickup. The crankcase must be vented to atmosphere or the PCV valve would have to be sized exactly right to just pull in the blowby gases and not change the crankcase pressure at various throttle positions. Assuming that the crankcase is vented, the PCV valve would be sized to pass the blowby gases and the ventilation air. The amount of ventilation air would be kept small since this eventually becomes a portion of the induction air.

Ventilation air could be admitted to the crankcase by means of a two-way relief valve. The incoming relief valve could be set to open just below ambient pressure and sized, in relation to the PCV valve, to limit the crankcase pressure to less than a few inches of water, or whatever is required by the seals. The only reason for the outgoing relief valve is to prevent the crankcase pressure from exceeding a few inches of water in the event the blowby gases suddenly increased or the PCV valve malfunctioned and could not pass the necessary flow. The high water content of the blowby gases may require that the PCV valve and lines be insulated and heated. Location of the PCV valve and lines to take advantage of available heat from the crankcase, oil sump or exhaust stacks may be necessary. It may be desirable to mount both the PCV valve and relief valve integral with the crankcase to provide a simple direct source of heat or at least the possibility of thawing in the event that icing occurred on startup.

Implementation of a PCV system on a turbocharged or supercharged engine is more complicated. If the crankcase gases are introduced into the induction system downstream of the throttle plate, a higher-pressure pump will be required than if the admission is upstream of the throttle plate. Thus, for a given installation, the highest expected ram pressure above ambient can be established and the pump can be matched to the system. A simple diaphragm pump, similar to the typical automotive fuel pump, can be used to drive the crankcase gases into the induction system.

The pump could be driven by a camshaft lobe or eccentric. The pump capacity would be such that the maximum blowby gases likely to occur and some ventilation air would be pumped into the induction system against the highest ram pressure likely to be encountered by the particular engine/air-frame combination. In the event of a pump malfunction, the pump would provide a check-valve function and the crankcase would vent the atmosphere through the two-way relief valve. The pump maximum output flow rate is a function of engine rpm and the blowby gases flow rate also varies somewhat proportional to engine speed.

The same considerations for heating of the lines to prevent icing apply to this system as they do for the normally aspirated engine. Blowby gases are usually in the order of 1 to 2 percent of the maximum induction air flow rate. The total ventilation air flow plus the blowby gases would probably be about 2 to 3 percent of the maximum induction air flow rate. Since the induction air flow rate has a flow range of approximately 20 to 1 from WOT to idle and a speed range of approximately 5 to 1, the PCV pump would provide approximately 5 percent of the idle air flow requirement for the concept discussed.

Cost Considerations

From the foregoing it is apparent that an airworthy PCV system is considerably more complex than the automotive PCV system. The cost of a PCV system would vary with the application. Normally aspirated engines would probably have the simpler PCV system while turbocharged/supercharged engines would have the more complex and, therefore, more costly system. The development cost of each PCV system will have to be amortized over a fairly small quantity of engines and this cost is likely to be the bulk of the total PCV system cost to the user. It is not realistic to estimate any dollar value at this time for development of the various PCV system possibilities.

4.3.3 Exhaust Treatment Systems

Exhaust treatment systems encompass those devices which operate on the exhaust gases from the engine to change chemically the undesirable constituents to more tolerable products. This generally requires the presence of oxygen to convert the unburned fuel, hydrogen and carbon products. Since aircraft piston-type engines are normally operated richer than stoichiometric and will probably continue to be partially operated that way, a source of air will be required to provide the necessary oxygen for the exhaust treatment system.

Potential candidates for aircraft exhaust treatment systems are: the straight secondary air system; the thermal reactor system; and the catalytic convertor system. In the straight secondary air system, air is introduced into each exhaust port to combine with the unburned fuel present, and the combined gases flow out through an essentially standard exhaust stack system. The thermal reactor system is essentially the same except that a thermally insulated combustion zone with recirculating passages is provided to minimize the heat loss from the exhaust gases and to provide longer residence time for the gases in the high-temperature zone. Air is admitted close to the exhaust port of each cylinder, and the thermal reactor is placed as close as possible to cylinders to further minimize heat losses.

The catalytic convertor may be located a longer distance from the engine exhaust ports because the catalytic element can initiate the oxidation of the unburned fuel at lower temperatures than the secondary air or thermal reactor systems. Thus, more flexibility in the installation is possible. The air injection point is apparently not critical, although the closer it is to the exhaust port, the better the mixing and consequently more complete conversion is possible.

All of the above systems require an air source or pump. The most reasonable air pumps at the present time appear to be the automotive vane-type pumps or the centrifugal or axial flow blowers as used for supercharging aircraft piston engines. The positive displacement Roots-type compressor appears to be too large and heavy to be a candidate for light piston-engine aircraft.

Possible Approaches

The secondary air system is the simplest and lightest of the three approaches. The change in weight of the exhaust system may be in the order of a few pounds because of the extra tubing for manifolding the air to the various cylinder exhaust stacks. Some radiation shielding may be required since the stacks will be somewhat hotter than present practice. The bulk of the system weight will be in the air pump, associated bracketry and drive mechanism. The only known pump type which may be suitable for small engines is the automotive vane type. It may be possible to substitute aluminum base materials for much of the steel parts in present-day vane pumps to provide lower weight. It is estimated that an air pump for a 100 HP engine may have an installed weight of approximately 10 lbs. The required air pump size is reduced as the engine air-fuel ratio approaches stoichiometric. Thus, until the air-fuel ratio requirements are better defined it is difficult to estimate a total system weight. Recall that the simple secondary air system requires an exhaust gas temperature of approximately 1100°F, or more, to obtain "light-off" of the reaction. The exhaust treatment matrix, Figure 3-11, indicated the effects of various parameters on the operation of a secondary air system. No operation of a secondary air system appears likely at low power outputs, i.e., ground operation, and overtemperature conditions may occur at certain combinations of air-fuel ratio, timing, power output and percent secondary air as shown in the same figure. Thus, the simple secondary air system has a somewhat narrow band of application in terms of an LTO cycle. It appears to be available for flight modes, provided overtemperature-producing combinations of parameters are avoided.

The weight of a secondary air system would be from one to several times the weight of a standard exhaust system. The complexity would be considerably greater and the expected reliability would be less by virtue of going from a passive exhaust stack to a moving-part system. A secondary air system could probably be added to the engine installation in most aircraft with little interference with other equipment within the cowling.

A thermal reactor installation on an aircraft engine would be more difficult than the straight secondary air system. Most present aircraft engines of opposed cylinder design have both intake and exhaust ports on the under side of the cylinder head. The general design of the cylinder head with the intake elbow and induction tube, cooling fins and rocker cover would prevent mounting of a thermal reactor as close to the exhaust ports as would be desired, The main container of the thermal reactor could be located somewhere in the arc from straight down below the exhaust port to straight out to the side from the exhaust ports. In any position, it appears that the thermal reactor would likely interfere with the existing cowling on most aircraft. In all other aspects, the thermal reactor is quite similar to the straight secondary air system. A source of air is required, and again the automotive-style vane pump appears to be the best selection. The size of the pump would be dependent upon the amount of secondary air required. The closer the engine is operated to stoichiometric, the less fuel would remain in the exhaust gases and, consequently, the smaller the pump size that would be required.

By definition, a well-designed thermal reactor minimizes the heat loss from the exhaust gas. The result would probably be less heat rejected under the cowling than from present exhaust stack designs. The necessity for heat muffs for cabin and induction air heating would remain; therefore, some form of muff would probably cover most of the exhaust stack from the thermal reactor to the exit end of the stack. The localized mass of the thermal reactor on the exhaust stack would probably require some strutting to keep the mechanical natural frequency of the exhaust stack system high enough to prevent fatigue failures caused by engine vibration. It is estimated that the weight of each thermal reactor would be in the order of one to three times the weight of the air pump for fully developed systems. Referring to the exhaust treatment system, effectivity matrix Figure 3-11, note that the thermal reactor of the test program aided the "light-off" of the exhaust gases. Oxidation of the exhaust gas took place at lower engine rpm's for a wider range at secondary air percentages, which was to be expected. The thermal reactor was almost identical to the secondary air system as far as overtemperature conditions were concerned. In fact, at the most retarded timing, a large percentage of the idle/taxi conditions experienced "light-off". Thus, the thermal reactor has a somewhat broader band of operating conditions than the straight secondary air system. It is estimated that the life and reliability of the thermal reactor system would be practically identical to the secondary air system.

A catalytic convertor exhaust system would have a gross system weight somewhere between the secondary air system and the thermal reactor system. It is estimated that each catalytic convertor would be about half the weight of the air pump. The same pump considerations apply to the catalytic convertor as to the other exhaust treatment systems. Since the catalytic convertor need not be located as close to the engine exhaust ports, a good possibility exists for using nearly standard-type exhaust stacks (with secondary air injectors) and consequently little or no cowling changes might be required. Again referring to the effectivity matrix of Figure 3-11, note that the catalytic convertor provides "light-off" capability at all taxi/idle conditions but has a slightly greater propensity to overheating at higher power levels for the equipment tested. It would appear that as engine air-fuel ratio approaches stoichiometric, with normal ignition timing and without excessive secondary air, the catalytic convertor system could cover all flight modes of the LTO cycle.

All the aforementioned exhaust treatment systems require a source of air for the oxidation of the fuel in the exhaust gas. It is likely that an air pump would be operated at some speed proportional to crankshaft speed. In a simple way then, the pump air output would tend to vary with engine air flow or speed. However, it is likely that the air flow from the pump would have to be controlled more precisely to provide the required amount of air to oxidize the remaining fuel in the exhaust gases. Thus, some form of valving would probably be required to meter the air flow to the exhaust treatment system. An additional consideration is the safety aspect of preventing overtemperature conditions in the exhaust system which might lead to mechanical failures or fire hazard. All the above exhaust treatment systems must include an air control system and some means of sensing excessive temperatures with high enough response rates to apply corrective action before a problem developes. The control system itself must be a "fail-safe" system. This means that, in the event of a problem secondary air to the exhaust treatment system would be reduced or cut off, thus extinguishing the reaction in the exhaust system.

The following is a summary of the weights of the experimental exhaust treatment system components used in the test program.

Component	Continental 0-200		Lycoming IO-540	
	lbs (Each)	lbs (Total)	lbs (Each)	lbs (Total)
Thermal Reactor	11.5	23.0	16	32
Catalytic Convertor	1.75	3.5	3.5	7
Air Pump (or) Turbocharger	7.3	14.6	15.0	15.0

SECTION 5

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APPENDIX A

DETAILS OF THE TEST AND EVALUATION PROGRAM

A.1 PHYSICAL SETUP

The dynamometer evaluations of both engines were conducted at the Bendix Research Laboratories Automotive Test Laboratory.

The dynamometer test cell contains a double-ended General Electric Universal Engine Dynamometer rated at 500 horsepower with maximum speeds to 5000 rpm, mechanical and electrical torque read-out, braking-reversing capability and emergency stop provisions. The motor-generator set and starter are in a separate room within the facility for noise and temperature isolation.

A control room is adjacent to the dynamometer cell, and contains the necessary controls to operate the dynamometer and engine and all the electronic readout instrumentation required for test control.

A special engine test stand was designed and fabricated for the aircraft engines tested on this project. The test stand was designed to accommodate both engines with minor adaptations. A motor-mount for the Continental 0-200 engine was specifically designed and fabricated. A standard aircraft motor mount was used for the Lycoming IO-540 test subassembly. Special engine-dynamometer adaptors were fabricated to mate the engine crankshaft with the dynamometer through coupling shafts. Flywheels of appropriate inertias were designed and fabricated in accordance with engine manufacturers' recommendations and installed and balanced between the engine output and the dynamometer coupling shaft.

Hydraulic mixture and throttle controls were installed in the control room.

Cooling air was provided by a medium-pressure industrial blower coupled with a 7-1/2 HP motor which could provide approximately 4000 CFM air at 6 inches of water pressure. The blower was mounted on the engine test stand. Necessary air ducts and engine cylinder baffles were fabricated to route the cooling air from the blower to the engine. A vent port was provided in the air duct to adjust the required level of cooling air as appropriate for the engine operational mode.

An oil cooler was installed within the cooling air duct to maintain engine oil temperature within the operational limits.

The engine crankcase blowby gases were vented outside the test area except for the tests with positive crankcase ventilation.

A photograph of the basic engine test installation is shown in Figure A-1 (a).

A block diagram of the test setup used for both engines is shown in Figure A-1(b).

A.2 MEASUREMENT AND INSTRUMENTATION

A.2.1 Ambient Conditions

Atmospheric pressure was observed at the beginning and end of each test series in a given day. The wet and dry bulb thermometer method was used to measure relative humidity. Ambient air (induction air) temperature was measured at each test point by a thermocouple installed at the inlet of a Meriam Flowmeter upstream of the engine air intake box. The temperature was read out on an appropriate thermocouple meter.

A.2.2 Engine Speed and Torque

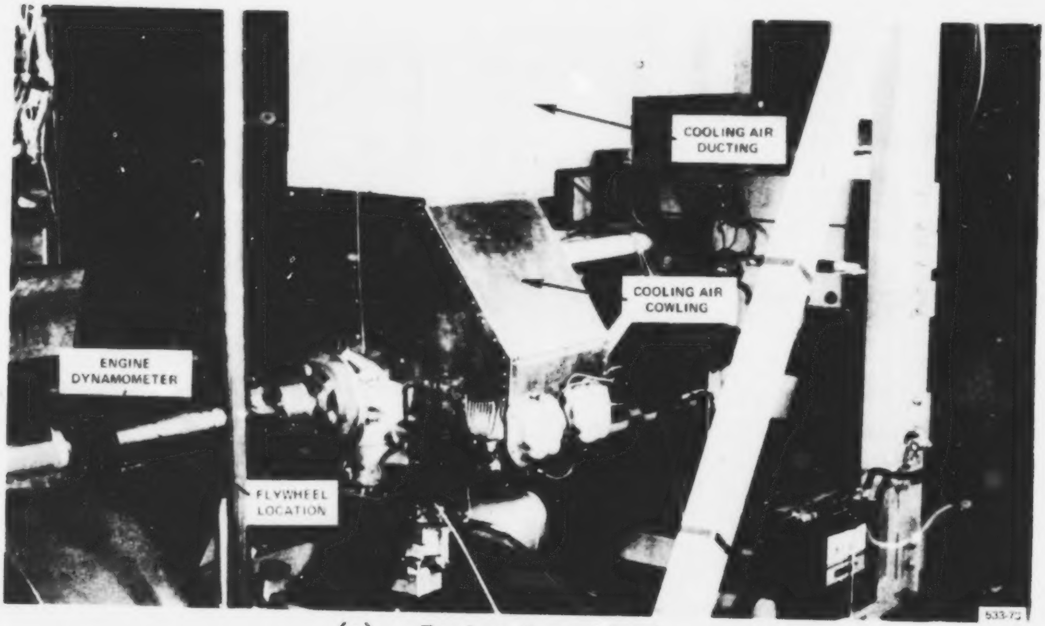
The dynamometer is equipped with closed-loop speed control. A magnetic pickup and four steel slugs mounted on the dynamometer shaft function as a pulse counter to monitor the engine speed. Desired engine speed for a given test point was established by adjusting the dynamometer speed and was readout on a digital frequency meter. Engine torque was established by adjusting the engine throttle position. Torque was measured by a Lebow load cell mounted at a fixed arm-length on the dynamometer and was read out on a digital voltmeter calibrated for direct value of torque in ft-lbs.

A.2.3 Induction Air Flow Measurement

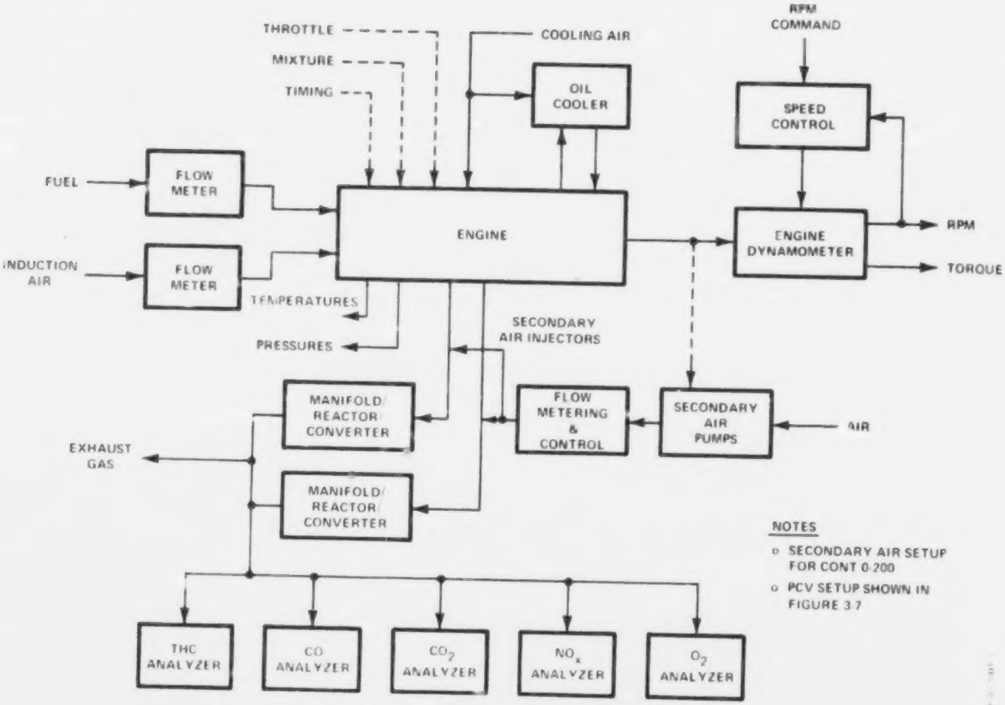
The measurement of induction air was essentially the same for both Continental 0-200 and Lycoming IO-540 engines. A Meriam Laminar Flowmeter, Model 50MC2-45, with a range of 0 to 400 CFM at 8 inches of water, was used in combination with a Foxboro, Model 613DL, pressure transducer. The output signal of the pressure transducer was fed to a digital voltmeter system calibrated to give a direct readout of air flow in CFM. Necessary conversions of CFM into mass flow by appropriate temperature corrections were made at the time of test, in accordance with the manufacturer's correction tables.

A.2.4 Fuel Flow Measurement

A Flotron Linear Mass Flowmeter, Model 10,000 Type II (0-225 PPH range at 15-20 psig supply), was used in combination with a Foxboro, Model 613DM, pressure transducer. The output of the pressure transducer was read on a DVM calibrated to give a direct readout in pounds/hr.


COOLING AIR DUCTING
COOLING AIR COWLING
ENGINE DYNAMOMETER
FLYWHEEL LOCATION
533-73

(a) - Engine Installation


THROTTLE
MIXTURE
TIMING
COOLING AIR
OIL COOLER
RPM COMMAND
SPEED CONTROL
FUEL
FLOW METER
INDUCTION AIR
FLOW METER
ENGINE
ENGINE DYNAMOMETER
RPM
TORQUE
TEMPERATURES
PRESSURES
SECONDARY AIR INJECTORS
MANIFOLD/ REACTOR/ CONVERTER
FLOW METERING & CONTROL
SECONDARY AIR PUMPS
AIR
EXHAUST GAS
MANIFOLD/ REACTOR/ CONVERTER
THC ANALYZER
CO ANALYZER
CO$_2$ ANALYZER
NO$_x$ ANALYZER
O$_2$ ANALYZER

NOTES

- SECONDARY AIR SETUP FOR CONT 0-200
- PCV SETUP SHOWN IN FIGURE 3.7

(b) - Block Diagram

Figure A-1 - Basic Engine Test Setup

A.2.5 Air-Fuel Ratio Measurement

Electronic signals from the induction air and fuel flow measurement systems were used to compute approximate air-fuel ratio for real-time display and guidance in setting test points. Computations were performed by a special-purpose computer in the control room and display was by a calibrated DVM output.

A.2.6 Temperature Measurements

In addition to induction air temperature, various other temperatures were measured with thermocouples.

Standard cylinder head thermocouples were installed under the spark plugs of the Continental 0-200 engine. Lycoming IO-540 cylinder head temperatures were measured with bayonet-type thermocouples installed at the locations provided on that engine.

Chromel/Alumel (C/A) thermocouple probes were installed in the exhaust manifolds for both engines approximately 2 to 4 inches away from the exhaust ports to monitor the temperatures of the individual exhaust port gases.

A C/A thermocouple was installed just downstream of the standard exhaust muff to record average exhaust gas temperatures.

Cowling temperature was measured at the point on the cowling a short distance away from the cylinder cooling fins below the engine.

Various other temperatures such as secondary air inlet temperature and reactor core temperatures were also monitored during exhaust treatment tests.

The various temperatures were recorded on Leads and Northrop Multiprint and Type K Esterline Angus recorders with appropriate thermocouple adaptors in the 0-2000°F range.

Several of the more critical temperatures (e.g., one cylinder head, exhaust gas, secondary air inlet, reactor core and oil temperatures) were simultaneously monitored on meter relays to monitor engine operation during the tests.

A.2.7 Oil Pressure and Manifold Absolute Pressure

Oil pressure was observed for both the engines to ensure appropriate oil pressure build-up during start-up and to observe safe limits during test runs.

Manifold absolute pressure was measured by a Meriam Model 11A10WM, Mercury Manometer.

A.2.8 Emissions Measurements

The procedure for the measurement of emissions was essentially as described in the Proposed Federal Standards of December 12, 1972. A diagram of the emissions measurement setup is given in Figure A-2. The emission cart contained the following analyzers.

THC - (ppm-Propane)	Beckman Model 108A FID with 0 to 10,000 PPM ranges and intermediate range selections.
CO - (%)	Beckman Model 315A NDIR calibrated for a 0 to 14% range.
CO_2 - (%)	Beckman Model 315A NDIR calibrated for a 0 to 15% range.
NO/NO_x - (ppm)	Thermo Electro Corp. NO_x analyzer with chemiluminescent ranges of 0 to 10, 25, 100, 250, 1000, 2500 ppm.
O_2 - (%)	Beckman Model 777 oxygen analyzer.

A 1/4-inch stainless steel tube sampling probe with 1/16-inch diameter orifices spaced 1/4 inch axially was installed downstream of the exhaust pipe "T" and oriented perpendicular to the exhaust flow path.

The exhaust gas sampling tube (3/8-inch in diameter) to the chemiluminescent analyzer was heated with electrical tapes to maintain the sample temperature above the dew point (approximately 150°F). No water removal devices were used for that portion of the exhaust gas sampled by the chemiluminescent analyzer.

Sample transfer from the probe to the analytical instruments was through stainless steel or Teflon lines. Sample transport time from the engine to the instruments was less than 2 seconds.

Electric output signals from the CO, CO_2, THC and NO_x analyzers were recorded on two dual-channel Texas Instrument recorders. The data value for oxygen was read out from the analyzer meter and manually recorded.

A.3 PROCEDURES

A.3.1 Engine Start-up

A routine daily inspection check of the instrumentation and the engine was performed before starting up the dynamometer.

After calibration of the instruments (e.g., air flow, fuel flow, torque) and emission analyzers, the dynamometer was started with the mixture cut off and the throttle in the closed position. Oil pressure was checked to make sure that the oil came up to the

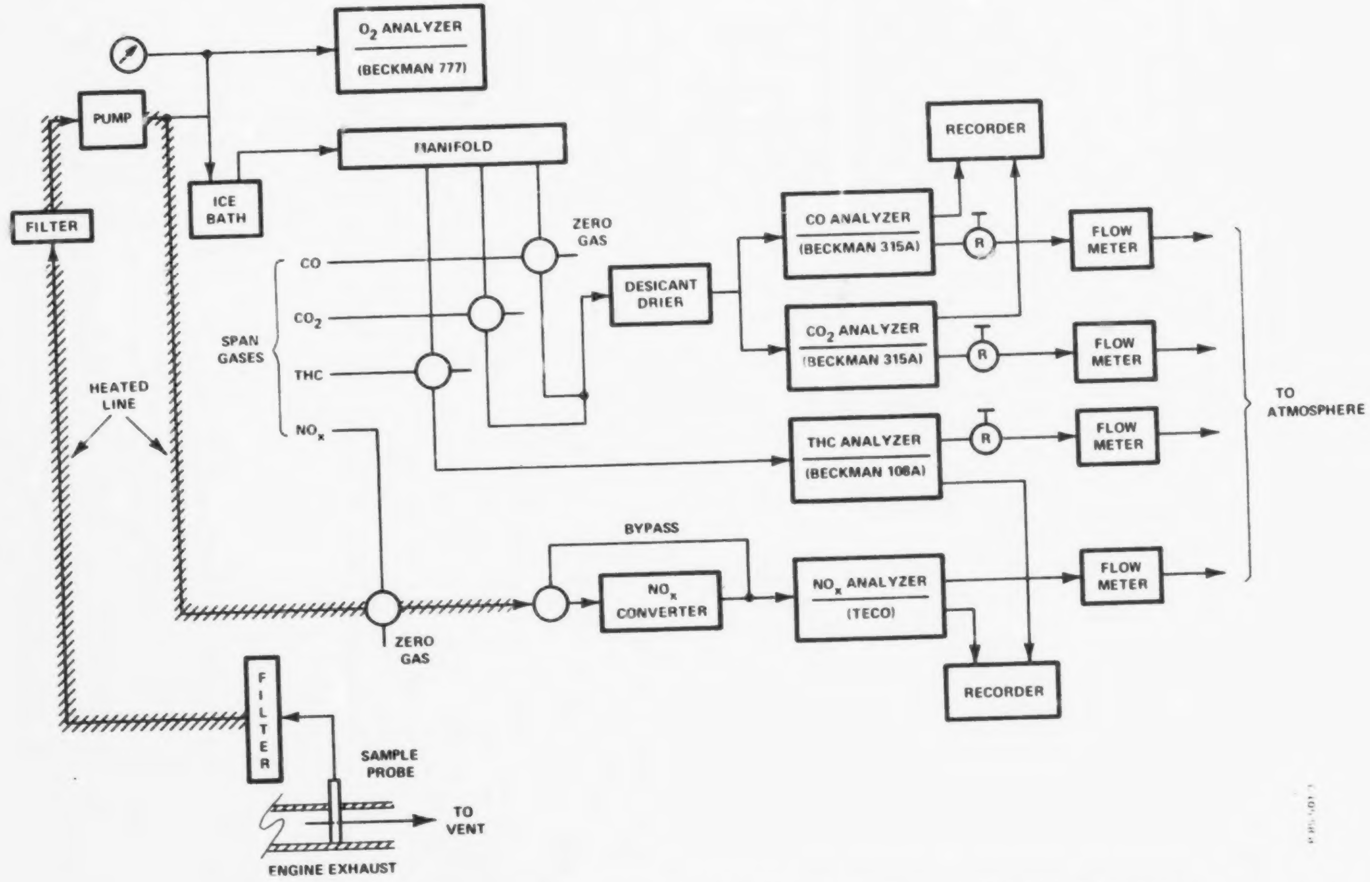

O2 ANALYZER
(BECKMAN 777)
PUMP
MANIFOLD
ICE BATH
FILTER
ZERO GAS
CO
CO2
THC
NOx
SPAN GASES
HEATED LINE
DESICANT DRIER
CO ANALYZER
(BECKMAN 315A)
CO2 ANALYZER
(BECKMAN 315A)
THC ANALYZER
(BECKMAN 108A)
NOx ANALYZER
(TECO)
R
RECORDER
FLOW METER
TO ATMOSPHERE
BYPASS
NOx CONVERTER
ZERO GAS
FILTER
SAMPLE PROBE
TO VENT
ENGINE EXHAUST

Figure A-2 - Exhaust Emissions Sampling and Instrumentation Diagram recommended value within 60 seconds. After the engine was turned over with the dynamometer, the throttle was opened slightly and the mixture was advanced to full rich with both magneto switches on. The engine was run to a speed slightly above idle/taxi while the oil and cylinder head temperatures came up to a recommended level before turning the cooling air on.

A.3.2 Cooling Air Selection

The engine cooling air flow rate was adjusted by venting a portion of the air provided by the blower so that the desired pressure drop existed across the engine. The pressure drop selected was based on the dynamic pressure corresponding to an air speed representative of the flight mode for an airframe utilizing the particular engine. The pressure drops for the idle/taxi modes were selected arbitrarily to provide more air flow than ordinarily exists in an actual airframe installation to allow for the continuous operation on the dynamometer. Table A-1 indicates the pressures used for each engine at the various flight mode rpm's.

A.3.3 Testing and Data Collection

Dynamometer speed was adjusted to the desired values and the throttle was opened to provide the engine torque at the desired test speed. The desired air-fuel ratio was obtained by adjusting the mixture setting and trimming the test torque value by adjusting throttle position. The amount of engine cooling air was adjusted as indicated in Table A-1 above.

Sampling of the exhaust was started after the operating conditions were stabilized. Pertinent engine data were recorded. The air-fuel ratio was varied at the same engine speed to obtain tests for the other two air-fuel ratios according to the test matrix. Engine speed was varied by alternating high and low power runs to avoid spark plug fouling.

The test points designated by "R" in Appendices B and C were repeat points to check the repeatability of the engine and emission data.

A.4 DATA ANALYSIS EQUATIONS AND A SAMPLE CALCULATION

The various data collected during test runs were processed by using the following equations. Pertinent data and calculated results are tabulated in Appendices B and C. A sample calculation is given to show the method of data reduction. Test points 10-1 and 10-4 from the Continental 0-200 secondary air test (28° BTDC ignition timing) are selected for the example, with the following data gathered during the test run.

Table A-1 - Cooling Air Pressure at Test Modes

ENGINE	MODE	SPEED (RPM)	PRESSURE SELECTED (IN. H_2O)	PRESSURE ACHIEVED (IN. H_2O)
CONTINENTAL 0-200	TAXI/IDLE (OUT)	900	1.0	1.0
	APPROACH	1950	2.0	2.0
	TAKEOFF & CLIMBOUT	2750	4.0	4.0
	IDLE/TAXI (IN)	1100	1.0	1.0
LYCOMING IO-540	TAXI/IDLE (IN & OUT)	1000	1.0	1.0
	APPROACH	1900	3.0	3.0
	TAKE OFF	2400	6.0	4.5
	CLIMBOUT	2700	6.0	4.5

P-85 501 3

Test Point	RPM	Ignition Timing	A/F	Secondary Air
10-1	1950	28° BTDC	10:1	Zero
10-4	1950	28° BTDC	10:1	110% of stoichiometric (Effective air-fuel ratio in exhaust of 16.2)

Recorded Data (10-1)

RPM	Brake Torque ft-lbs	Baro. Pressure psia	Rel. Humidity
1955	95	14.35	60%

Air Flow (CFM)	Fuel Flow, WF	Inlet Air Temp (T) °F
75.1	31.0 lbs/hr	90

Measured Concentrations

HC-PID (ppm)

Propane Equivalent	CO (%)	NO (ppm)	CO_2 (%)	O_2 (%)
1540	11.0	27	5.9	0.5

A.4.1 Induction Air

Induction air flow was measured in CFM uncorrected for ambient conditions. The following equation corrects volume flow rate (CFM) into mass flow rate (lbs/hr) for 70°F ambient temperature and standard sea level pressure of 14.7 psia.

W_a = Corrected air flow (lbs/hr)

$$= \left[\text{CFM } [1 + 0.0033(70-T)] \times \left(\frac{\text{Baro. Press.}}{14.7} \right) 4.52 \right]$$

where

$[1 + 0.0033(70 - T)]$ is the temperature correction factor for the laminar flow meter.

Example
(10-1)

$$W_a = 75.1 \, [1 + 0.003 \, (70-90)] \times \frac{14.35}{14.7} \times 4.52 = 309.5 \text{ lbs/hr.}$$

A.4.2 Air-Fuel Ratio

Measured fuel-air ratio = $\frac{W_F}{\text{CFM} \times 4.52}$, uncorrected for ambient conditions.

$$\text{Corrected Air-fuel ratio (A/F)} = \frac{W_a}{W_f}$$

where

W_F = the fuel flow rate, lbs/hr

Example (10-1) $$AF = \frac{309.5}{31.0} = 9.98$$

A.4.3 Emissions Concentration

The emission concentrations are corrected for humidity in the case of NO_x. Where indicated as "corrected", measured emissions concentrations were modified to normalize the effect of varied air-fuel ratio to allow a direct comparison of emissions on a concentration basis. Current practice is to use mass bases of comparison, and both methods are used in the data computations. The Dilution Factor (D.F.) described below is used to normalize raw emissions concentration values to the stoichiometric ratio. Raw concentration values are used to compute mass emissions as described in A.4.4 through A.4.7 below.

- Humidity Correction Factor (K_H) = $\frac{1}{1-0.0047(H-75)}$

where H is humidity in grains of moisture per lb. of dry air.

Example (10-1) H = 65 grains/lb of dry air for ambient temperature of 90°F and 60% relative humidity (from standard hygrometric chart)

$$K_H = \frac{1}{1-0.0047(65-75)}$$
$$= 0.955$$

- Dilution Factor (D.F.) = $\frac{14.5}{\%\ CO_2 + 1/2\%\ CO + \frac{3 \times THC\ (propane)}{10,000}}$

Example (10-1)

$$D.F. = \frac{14.5}{5.9 + 1/2 \times 11.0 + \frac{3 \times 1540}{10,000}}$$
$$= 1.22$$

- Oxides of Nitrogen (NO_x) Concentration

$$NO_C = NO \times K_H \times D.F.$$

where

NO_C = Corrected NO_x concentration in ppm

NO = Observed NO_x concentration in ppm

K_H = Humidity correction factor

D.F. = Dilution correction factor

Example (10-1) $NO_C = 27 \times 1.22 \times 0.955 = 31.4$ ppm

- Carbon Monoxide and Carbon Dioxide Concentration

$$CO_C = CO \times D.F.$$

$$CO_2C = CO_2 \times D.F.$$

where

CO_C = Carbon monoxide concentration in percent, corrected

CO_2C = Carbon dioxide concentration in percent, corrected

CO = Observed carbon monoxide concentration in percent

CO_2 = Observed carbon dioxide concentration in percent

D.F. = Dilution factor

Example (10-1) $CO_C = 11.0 \times 1.22 = 13.3\%$

$CO_2C = 5.9 \times 1.22 = 7.2\%$

- Total Hydrocarbon Concentration

$$HC_C = HC \times 3 \times D.F.$$

where

HC_C = Total hydrocarbon concentration in ppm - carbon equivalent

HC = Observed hydrocarbon propane equivalent in ppm

Example (10-1) $HC_C = 1540 \times 3 \times 1.22 = 5590$ ppm C

A.4.4 Mass Emissions Rates

$$V_E = \text{Exhaust flow rate} = \frac{W_a + W_F}{P_E} \ (ft^3/hr)$$

$$P_E = \text{Density of exhaust} = 0.0075 \times \frac{E_m}{28.96}$$

E_m = Exhaust molecular weight for the given A/F

$= 21.2 + 0.52 \frac{W_a}{W_F}$ (Equation derived from published curve by Continental Motors)[14]

Therefore

$$V_E = (309.5 + 31) \times \frac{28.96}{0.075} \times \frac{1}{21.2 + 0.52 \times \frac{309.5}{31}}$$

$$= 4980 \ ft^3/hr$$

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[14] Figure B-5, Section 11, p. 5.

- Oxides of Nitrogen, lb/hr

$$NO_{xm} = \frac{NO}{10^6} \times V_E \times MNO_2 \times K_H$$

where

NO_{xm} = Oxides of Nitrogen in lbs/hr

MNO_2 = Density of NO_2 = 0.119 lbs/ft^3

Example (10-1) $NO_{xm} = \frac{27}{10^6} 4980 \times 0.119 \times 0.955$

$= 0.0152$ lbs/hr

The exhaust gas sample (except for NO_x analysis) was passed through an ice bath maintained at 32°F to remove water resulting from combustion as required by the CO and CO_2 instrumentation. The CO and THC concentration measurements were therefore recorded on a dry basis and required the following calculations to account for the water removal to allow proper calculation of emission rates.

Water Correction Factor, CF_w

$$CF_w = (1 - \alpha \frac{W_F}{W_a})$$

where

α = Hydrogen/carbon atom ratio

= 2.12 for this representative gasoline with formula $C_8 H_{17}$[14]

Example (10-1) $CF_w = 1 - 2.12 \times \frac{31.0}{309.5}$

$= 0.788$

- Carbon Monoxide, lbs/hr

$$CO_m = \frac{CO}{100} \times V_E \times MCO \times CF_w$$

---

[14] p. 8-1

where

CO_m = carbon monoxide in lbs/hr

MCO = Density of CO = 0.0726 lbs/ft^3

Example (10-1) $CO_m = \frac{11.0}{100} \times 4980 \times 0.0726 \times 0.788$

$= 31.34$ lbs/hr.

- Total Hydrocarbons, lbs/hr

$$HC_m = 3 \times \frac{HC}{10^6} \times V_E \times MHC \times CF_w$$

where

HC_m = total hydrocarbon in lbs/hr

HC = Observed hydrocarbon propane equivalent in ppm

MHC = Density of HC = 0.0359 lb/ft^3

Example (10-1) $HC_m = 3 \times \frac{1540}{10^6} \times 4980 \times 0.0359 \times 0.788$

$= 0.651$ lbs/hr

A.4.5 Emissions in lb Mass/1000 lbs Fuel

Emissions in lbs/1000 lbs fuel were calculated in the following manner

$$\text{Emission in lbs/1000 lbs fuel} = \text{Emission in lbs/hr} \times \frac{1000}{W_F}$$

- Hydrocarbon $= HC_m \times \frac{1000}{W_F}$

$= 0.651 \times \frac{1000}{31.0}$

$= 21.0$ lbs/1000 lbs fuel

- Carbon Monoxide $= CO_m \times \frac{1000}{W_f}$

$= 31.34 \times \frac{1000}{31.0}$

$= 1011$ lbs/1000 lbs fuel

- Oxides of Nitrogen $= \text{NO}_{xm} \times \frac{1000}{W_F}$

$$= 0.0152 \times \frac{1000}{31.0}$$

$$= 0.49 \text{ lbs/1000 lbs fuel}$$

A.4.6 Emissions in lb Mass/BHP-HR

Emission in pound mass per brake horsepower per hour were calculated in the following manner.

$$\text{Brake Horsepower (bhp)} = \frac{2\pi \times \text{Brake Torque} \times \text{RPM}}{33000}$$

$$\text{Example (10-1)} \quad \text{BHP} = \frac{96 \times 1955}{5252}$$

$$= 35.71$$

Emissions in lbs/BHP-Hr = (Emission in lb/hr) ÷ (BHP)

- Total hydrocarbon, $= \text{HC}_m \times \frac{1}{\text{BHP}}$

$$\text{Example (10-1)} \quad = 0.651 \times \frac{1}{35.71}$$

$$= 0.0182 \text{ lbs/BHP-HR}$$

- Carbon Monoxide $= \text{CO}_m \times \frac{1}{\text{BHP}}$

$$\text{Example (10-1)} \quad = 31.34 \times \frac{1}{35.71}$$

$$= 0.878 \text{ lbs/BHP-HR}$$

- Oxides of Nitrogen $= \text{NO}_{xm} \times \frac{1}{\text{BHP}}$

$$\text{Example (10-1)} \quad = 0.0152 \times \frac{1}{35.71}$$

$$= 0.00042 \text{ lbs/BHP-HR}$$

A.4.7 Emissions in Lbs/Mode

Emissions in pounds per mode were calculated in the following manner. Emission (lbs/mode) = Emission (lb/hr) x $\frac{T}{60}$

where

T is the time in each mode as prescribed by the proposed federal standards for piston-engine aircraft.

Mode	Time (T)
Taxi/Idle (out)	12.0 min.
Takeoff	0.3 min.
Climbout	5.0 min.
Approach	6.0 min.
Taxi/Idle (In)	4.0 min.

- Total hydrocarbon (lbs/mode) $= HC_m \times \frac{T}{60}$

Example (10-1) $= 0.651 \times \frac{6}{60}$

$= 0.0651$ lbs/mode

- Carbon Monoxide (lbs/mode) $= CO_m \times \frac{T}{60}$

Example (10-1) $= 31.34 \times \frac{6}{60}$

$= 3.134$ lbs/mode

- Oxides of Nitrogen (lbs/mode) $= NO_{xm} \times \frac{T}{60}$

Example (10-1) $= 0.0152 \times \frac{6}{60}$

$= 0.00152$ lbs/mode

A.4.8 Air-Fuel Ratio from the Exhaust Components

Actual air-fuel ratio was set by the mixture control on the engine fuel control system and calculated as in A.3.2. A cross-check of the air-fuel ratio was performed by carbon balance analysis of exhaust gas components in the following manner.

- $$(A/F)_C = F_b \left[11.492\ F_C \left(\frac{1 + E/2 + D}{1 + E} \right) + \frac{120\ (1 - F_C)}{3.5 + E} \right]^*$$

---

*"Air/Fuel Ratios from Exhaust Gas Analysis," R. S. Spindt, SAE Paper 650507.[15]

where

$(A/F)_C$ = air-fuel ratio from exhaust gas analysis

$$F_b = \frac{\%\ CO + \%\ CO_2}{\%\ CO + \%\ CO_2 + \frac{3 \times HC}{10,000}}$$

Example (10-1) $$F_b = \frac{11.0 + 5.9}{11.0 + 5.9 + \frac{3 \times 1540}{10,000}} = 0.9734$$

F_C = fraction of carbon in fuel = 0.869

$$E = \frac{\%\ CO}{\%\ CO_2} = \frac{11.0}{5.9} = 1.8644$$

$$D = \frac{\%\ O_2}{\%\ CO_2}$$

$$= \frac{0.5}{5.9} = 0.085$$

$$(A/F)_C = 0.9734 \left[11.492 \times 0.869 \left(\frac{1 + 0.9322}{1 + 1.8644} \right) + \frac{120\ (1 - 0.869)}{3.5 + 1.8644} \right]$$

$$= 9.7$$

A.4.9 Brake Specific Fuel Consumption (BSFC)

Brake specific fuel consumption is the amount of fuel consumed per brake horsepower per hour and was calculated as follows.

- $$BSFC = \frac{W_F}{BHP}$$

Example (10-1) $$BSFC = \frac{31.0}{35.71} = 0.868$$

A.4.10 Exhaust Air Injection Flow Rates

The stoichiometric air-fuel ratio used for the representative gasolines is 14.7. The corresponding A/F values of various percents of stoichiometric are as follows:

90% of stoichiometric = 0.9 x 14.7 = 13.23 A/F

100% of stoichiometric = 1.0 x 14.7 = 14.7 A/F

110% of stoichiometric = 1.1 x 14.7 = 16.17 A/F

The following equation computes the equivalent amount of air (W_s, percent of induction air) that needs to be injected to bring the exhaust gas composition to the required percent of stoichiometric.

- $$W_s = \frac{N \times 14.7 - (A/F)_e \times 100}{(A/F)_e}$$

where

$(A/F)_e$ = the engine A/F ratio

N = Percent of stoichiometric

The following table shows the percent of secondary air injected relative to induction air required at 10, 11.5 and 13.0 engine A/F for 90, 100 and 110 percent of stoichiometric in the exhaust.

Engine A/F Ratio	Exhaust Gas Composition (% of Stoichiometric)	Amount of Secondary Air (% of Induction Air)
10:1	90	32.3
11.5:1	90	15.1
13:1	90	1.8
10:1	100	47.0
11.5:1	100	27.8
13:1	100	13.1
10:1	110	61.7
11.5:1	110	40.6
13:1	110	24.4

A.4.11 Calculations with Secondary Air

Calculations made in connection with secondary air tests were as follows. Pertinent data for example calculation are from Run 10-4 of the Continental 0-200 secondary air test series.

Flow, CFM	Temp.	Press. psig	% $(CO)_S$	$\%(CO_2)_S$	$(NO_X)_S$PPM	$(HC)_S$	$(O_2)_S$%
36.00	170°F	3.8	1.4	13.5	47	9	1.65

- Conversion of Measured CFM into Lbs/Hr

The amount of secondary air injected into the exhaust manifolds was calculated in the following manner.

$$W_s = \text{Secondary air flow (lbs/hr)}$$

$$= 4.52 \times \text{CFM} \times C_T \times C_P$$

where

CFM = Secondary air flow (ft^3/min)

C_T = Correction factor for temperature

$$= \frac{530}{460 + t}$$

and C_P = Pressure correction factor

$$= \frac{P + BP}{14.7}$$

where

t = Secondary air temperature, °F

P = Secondary air pressure, psig

BP = Ambient barometric pressure (psia)

Example (10-4) $W_s = 4.52 \times (36.0) \times \frac{530}{460 + 170} \times \frac{3.8 + 14.35}{14.7}$ *

$$= 169.01 \text{ lbs/hr}$$

Air-fuel ratio with secondary air is calculated by the summation of the induction air and secondary air and dividing it by the fuel flow rate.

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[*] 14.7 was inadvertently used in the secondary-air calculations rather than the actual ambient pressure. This results in a maximum approximate 2 percent error in that data set.

- Mass Emission Rates, lbs/hr

Exhaust gas velocity $(VE)_s$ with secondary air $= \dfrac{W_a + W_s + W_F}{(P_E)_s}$

where

$$(P_E)_s = 0.075 \times \frac{\left(E_m\right)_s}{28.96}$$

and

$$(E_m)_s = 21.2 + 0.52 \frac{W_a + W_s}{W_F}$$

Therefore,

$$(V_E)_s = \frac{(309.5 + 172.2 + 31.0)}{(21.2 + 0.52 \times 15.54)} \times \frac{28.96}{0.075} = 6761 \text{ ft}^3/\text{hr}$$

- Water Correction Factor $(CF_w)_s$

$$(CF_w)_s = 1 - \alpha\left(\frac{W_F}{W_a + W_s}\right)$$

$$= 1 - 2.12\left(\frac{31.0}{309.5 + 172.2}\right)$$

$$= 0.864$$

- Hydrocarbon mass emission $(HCM)_s$, lbs/hr

$$(HCM)_s = \frac{(HC)_s}{10^6} \times 3 \times (VE)_s \times MHC \times (CF_w)_s$$

$$= \frac{9}{10^6} \times 3 \times 6761 \times 0.0359 \times 0.864$$

$$= 0.00566 \text{ lbs}$$

Calculated air-fuel ratio at the exhaust $= \frac{W_a + W_s}{W_F}$

Example (10-4) $= \frac{309.5 + 172.2}{31.0}$

$= 15.54$

Dilution Factor (D.F.) $= \frac{14.5}{\% CO_2 + 1/2\% CO + \frac{3 \times THC\ (propane)}{10,000}}$

Example (10-4) $= \frac{14.5}{13.5 + \frac{1}{2} \times 1.4 + \frac{3 \times 9}{10,000}}$

$= 1.01$

- Emission Concentrations
  - Total Hydrocarbon $= 3 \times (HC)_s \times D.F.$

    $= 3 \times 9 \times 1.01$

    $= 27.3$ ppm
  - Carbon Monoxide $= (CO)_s \times D.F.$

    $= 1.4 \times 1.01$

    $= 1.41$ percent
  - Carbon Dioxide $= (CO_2)_s \times D.F.$

    $= 13.5 \times 1.01$

    $= 13.6$ percent

- Oxides of Nitrogen $= (NO)_s \times D.F. \times K_H$

$$= 47 \times 1.01 \times 0.955$$

$$= 45.3 \text{ ppm}$$

- Carbon Monoxide Mass Emissions $(COM)_s$, lbs/hr

$$(COM)_s = \frac{(CO)_s}{100} \times (VE)_s \times MCO \times (CF_w)_s$$

$$= \frac{1.4}{100} \times 6761 \times 0.0726 \times 0.864$$

$$= 5.93 \text{ lbs/hr}$$

- Nitric Oxide Mass Emissions $(NO_{xm})_s$, lb/hr

$$(NO_{xm})_s = \frac{(NO_x)_s}{10^6} \times (VE)_s \times MNO \times K_H$$

$$= \frac{47}{10^6} \times 6761 \times 0.119 \times 0.955$$

$$= 0.036 \text{ lbs/hr}$$

The remainder of the calculations such as emission lb/1000 lb-fuel, lb/BHP-Hr and lb/mode are treated in the same way as in the earlier example by multiplying emission in lb/hr by the respective correction factors.

APPENDIX B

DATA AND COMPUTED VALUES FOR CONTINENTAL 0-200 ENGINE

B1 - Baseline Engine Variables Evaluation

B2 - PCV Effects Evaluation

B3 - Secondary-Air Injection Evaluation

B4 - Thermal Reactor Evaluation

B5 - Catalytic Convertor Evaluation

APPENDIX B1

BASELINE ENGINE VARIABLES EVALUATION

O-200 ENGINE TEST DATA

FUEL: 80/87 Leaded MAG SETTING: 28° B.T.D.C. [illegible] ENGINE HOURS: 100.4 TEST CONDITIONS: Baseline

TEST #	DATE & TIME	R.P.M	TORQUE FT. lbs	MAN. ABS. PRESS. IN HG	BARO. PRESS. IN. HG	REL. HUM. %	INLET AIR TEMP. °F	AIR FLOW CFM	FUEL FLOW PPH	F/A RATIO OBS.	F/A RATIO COR.	CYL. EXHAUST PORT TEMP °F #1	#2	#3	#4	TEMPERATURES °F OIL	CYL. HEAD	COWLING	EXH GAS	OIL PRESS PSI
1	7-28-72 1-25 PM	[illegible]	21	12.63	29.82	70	79	16.6	7.2	.0971	9.94	860	850	865	700	120	195	110	600	33.5
2	1-35 PM	900	22	11.81	"	"	79	15.9	6.0	.0846	11.56	820	815	840	745	110	190	100	585	33.5
3	1-40 PM	902	22	11.61	"	"	80	15.2	5.1	.0744	12.98	830	820	850	750	110	195	110	560	33
4 4-R	11-15 AM 1-50 PM	1103 1101	33 34	12.68 12.49	"	"	84 82	21.5 22.8	9.2 9.8	.0945 .0954	10.04 10.06	940 940	930 920	980 980	895 970	150 165	210 215	120 130	700 710	33.5 34
5	11-20 AM	1103	33	11.81	"	"	84	19.8	7.3	.0824	11.65	900	890	960	850	145	210	120	660	33.5
6	11-20 AM	1101	23	11.57	"	"	83	19.2	6.3	.0737	13.14	940	940	1010	910	150	220	120	675	33.5
7	10-30 AM	1704	74	16.14	"	"	86	45.2	19.6	.0945	9.94	1150	1140	1140	1110	180	265	130	970	35
8	10-20 AM	1707	75	15.10	"	"	86	44.5	16.5	.0820	11.51	1190	1180	1210	1160	185	285	130	980	35
9	[illegible]	1703	74	16.06	"	"	88	42.1	13.6	.0719	13.13	1250	1230	1280	1250	195	300	140	1020	34.5
10	11-40 AM	1947	96	[illegible]	"	"	86	[illegible]	28.8	[illegible]	[illegible]	1145	1130	1160	1140	180	295	135	1045	34.5
11	[illegible]	1955	96	[illegible]	"	"	90	63.9	23.3	.0805	11.56	1190	1170	1200	1195	190	310	140	1090	36
12	11-50 AM	1949	96	18.81	"	"	92	60.2	19.4	.0711	12.79	1255	1250	1325	1280	220	320	145	1185	34.5
13 13-R	2-14 PM 3-15 PM	2758 2757	153 152	[illegible] [illegible]	"		96 96	141.0 141.0	58.6 59.1	[illegible] .0917	9.95 9.98	1470 1470	1410 1460	1200 1230	1220 1240	270 240	435 455	200 180	1300 1310	35 38.5
14	2-12 PM	2754	165	28.19	"	"	93	138.0	50.6	.0802	11.38	1490	1470	1240	1240	250	465	180	1310	36.5
15	[illegible]	[illegible]	[illegible]	[illegible]		"	[illegible]	[illegible]	[illegible]	[illegible]	13.12	[illegible]	1540	1420	1260	290	495	205	1400	38.5

Chart # 1

O-200 ENGINE EMISSION DATA

TEST #	CORRECTED CONCENTRATION				lbm/hr			lbm/1000 lbm fuel			lbm/BHP-HR			lbm/cycle/rated HP			A/F *
	THC-C PPM	CO %	NOx PPM	CO2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC + $\times 10$	CO	NOx 10^{-6}	
1	20,564	11.89	16.1	6.64	.635	7.42	.002	87.05	1016.4	.23	.177	2.06	.0005	3.18	.0037	.8	8.43
2	11,345	11.89	21.6	7.56	.331	6.99	.002	55.08	1165.4	.35	.088	1.85	.0006	1.65	.0035	1.0	9.48
3	5,861	6.84	48.8	10.64	.160	3.77	.004	31.40	739.8	.87	.042	1.00	.0012	.80	.0019	2.2	11.44
4	16,959	13.00	28.3	6.44	.632	9.78	.003	68.69	1063.5	.38	.091	1.41	.0005	9.48	.0147	5.2	7.74
4-2	16,028	13.42	13.1	6.33	.661	11.17	.002	67.48	1140.3	.18	.093	1.57	.0003	9.91	.0168	2.7	8.68
5	6,843	12.71	32.6	7.60	.243	9.10	.004	33.24	1246.5	.52	.035	1.31	.0006	3.64	.0136	5.7	9.58
6	3,254	5.95	106.7	11.34	.107	3.96	.012	17.03	629.0	1.85	.016	.57	.0017	1.61	.0059	17.5	11.95
7	8,336	14.42	25.5	6.60	.634	22.12	.006	32.32	1128.7	.33	.026	.92	.0003	0.53	.0018	.5	8.97
8	3,597	10.68	114.5	8.94	.284	17.03	.030	17.21	1032.0	1.82	.012	.70	.0012	.24	.0014	2.5	10.93
9	2,490	5.93	517.5	11.43	.184	8.86	.127	13.55	651.7	9.34	.008	.37	.0053	.15	.0007	10.6	12.02
10	7,501	15.36	23.5	6.21	.831	34.35	.009	28.85	1192.6	.30	.023	.97	.0002	4.15	.0172	4.3	8.76
11	3,431	10.75	143.0	8.92	.365	23.12	.050	15.68	992.4	2.17	.010	.65	.0014	1.83	.0116	25.2	10.42
12	2,505	7.20	498.6	10.77	.259	15.02	.168	13.35	774.1	8.67	.007	.42	.0047	1.29	.0075	84.1	11.60
13	10,355	13.02	121.8	7.09	2.591	65.30	.101	44.21	1121.8	1.72	.032	.84	.0013	25.91	.0658	101.0	9.23
13-2	12,148	12.57	127.9	7.14	3.052	63.81	.107	51.65	1079.6	1.80	.038	.80	.0013	30.52	.0634	106.6	9.22
14	2,985	11.20	394.5	2.74	.729	55.25	.320	14.41	1091.7	6.32	.008	.64	.0037	7.29	.0553	319.8	10.32
15	2,123	4.96	1170.6	11.98	.452	22.45	.891	11.39	530.9	20.83	.005	.25	.0099	4.82	.0225	581.0	12.42

* A/F calculated on carbon balance from exhaust gas analysis.

Chart # 2

O-200 ENGINE TEST DATA

FUEL: 80/87 LEADED MAG SETTING: 27° 27 DC ENGINE HOURS: 108.8 TEST CONDITIONS: Baseline

TEST #	DATE & TIME	R.P.M	TORQUE FT. lbs	MAN. ABS. PRESS. IN HG	BARO. PRESS. IN. HG	REL. HUM. %	INLET AIR TEMP. °F	AIR FLOW CFM	FUEL FLOW PPH	F/A RATIO		CYL. EXHAUST PORT TEMP °F				TEMPERATURES °F				OIL
										OBS.	COR A/	#1	#2	#3	#4	OIL	CYL. HEAD	COWLING	EXH GAS.	PRESS PSI
16	7-29-72 1-15 PM	905	22	12.05	29.52	60	93	13.5	7.7	[illegible]	10.03	820	790	[illegible]	[illegible]	175	210	130	680	31
17	12-30 PM	894	21	11.73	"	"	92	15.8	5.7	.0799	11.60	810	800	865	730	185	210	130	615	30
18	12-35 PM	903	21	11.62	"	"	90	14.9	4.8	.0719	13.08	820	810	890	790	170	210	130	570	32
19	12-05 PM	1105	31	13.46	"	"	90	24.0	10.0	.0925	10.11	970	960	1020	940	160	210	130	720	33.5
20	11-50 AM	[illegible]	31	12.05	"	"	90	20.7	7.5	.0810	11.63	930	920	990	870	185	225	130	650	32.5
21	11-55 AM	1095	31	11.54	"	"	[illegible]	19.5	6.2	.0717	13.23	950	940	1025	800	175	228	130	660	33
22	11-[illegible] AM	1706	73	18.16	"	"	92	53.2	[illegible]	.0925	9.06	1160	1170	1190	1160	175	295	145	1020	35
22-A	12-[illegible] PM	1706	73	18.31			97	53.1	[illegible]	.0922	9.93	1190	1170	1200	1155	185	285	145	1020	36
23	11-[illegible] AM	1707	73	17.91	"	"	98	48.5	17.9	.0811	11.49	1210	1190	1220	1180	175	295	140	1010	35.5
24	11-45 AM	1699	73	17.26	"	"	90	48.2	15.7	.0717	12.94	1180	1170	1305	1260	185	305	145	1050	35
25	12-22 PM	1957	96	21.47	"	"	96	75.6	31.5	.0915	9.92	1230	1215	1205	1175	215	320	150	1115	35
26	12-26 PM	1954	96	20.51	"	"	95	69.1	25.0	.0798	11.46	1270	1255	1280	1250	205	330	150	1140	35
26-B	12-3[illegible] PM	1956	96	20.57			95	69.4	25.0	.0794	11.51	1265	1245	1280	[illegible]	185	227	150	1140	36
27	12-[illegible] PM	1956	96	20.27	"	"	94	67.2	21.5	.0708	13.00	1305	1290	1250	1330	185	235	150	1185	35
28	12-57 PM	2750	150	28.19	"	"	104	142.0	57.9	.0895	9.89	1460	1440	1260	1240	270	445	185	1310	35
29	12-56 PM	2740	158	28.1[illegible]	"	"	102	140.3	56.0	.0784	11.36	1505	1490	1270	1260	230	450	180	1340	36
30	12-55 PM	2746	162	[illegible]	"	"	100	140.0	44.1	.0646	12.96	1590	1570	1395	1370	220	452	180	1425	38

Chart # 3

O-200 ENGINE EMISSION DATA

TEST *	CORRECTED CONCENTRATION				lbm/hr			lbm/1000 lbm fuel			lbm/BHP-HR			lbm/cycle/rated HP			A/F *
	THC PPM	CO %	NO$_x$ PPM	CO$_2$ %	THC	CO	NO$_x$	THC	CO	NO$_x$	THC	CO	NO$_x$	THC $\times10^{-4}$	CO	NO$_x$ $\times10$	
16	17,961	10.89	18.7	7.40	.5796	7.09	.0020	75.27	921.26	.26	.153	1.87	.0005	2.90	.0035	1.0	7.99
17	6,972	10.20	33.6	8.84	.1839	5.43	.0029	32.26	953.37	.52	.051	1.51	.0008	.92	.0027	1.5	10.31
18	4,942	6.44	47.1	10.93	.1237	3.26	.0037	25.78	678.81	.81	.034	.90	.0011	.62	.0016	2.0	11.65
19	13,703	11.97	22.4	7.28	.5111	9.02	.0028	51.11	902.04	.28	.078	1.38	.0004	7.67	.0135	4.2	9.28
20	5,394	10.23	47.2	8.99	.1893	7.25	.0055	25.24	966.34	.73	.029	1.12	.0009	2.84	.0109	8.3	10.43
21	3,360	6.21	86.9	11.20	.1111	4.15	.0095	17.94	668.76	1.54	.017	.64	.0015	1.67	.0062	14.3	11.85
22	7,203	14.35	32.8	6.75	.6365	25.60	.0096	28.54	1148.17	.43	.027	1.08	.0004	.53	.0021	.8	9.07
22-R	7,414	14.70	25.7	6.65	.7590	26.77	.0077	33.8	1195.20	.34	.032	1.13	.0003	.63	.0022	.6	8.28
23	4,041	11.39	75.3	8.54	.3437	19.56	.0212	19.20	1092.72	1.19	.015	.82	.0009	.29	.0016	1.8	10.18
24	2,776	6.73	287.7	10.97	.2345	11.56	.0206	14.94	736.53	5.13	.010	.49	.0034	.20	.0010	6.7	11.71
25	6,434	15.13	29.1	6.43	.8096	32.44	.0121	25.70	1220.18	.39	.023	1.07	.0004	4.05	.0192	6.1	8.90
26	3,574	11.53	108.1	8.52	.4202	27.98	.0431	17.17	1119.15	1.72	.012	.78	.0012	2.15	.0140	21.5	10.17
26-R	3,581	10.04	102.7	8.82	.4173	25.73	.0420	16.69	1029.15	1.68	.012	.72	.0012	2.09	.0129	21.0	10.35
27	2,734	7.29	378.9	10.72	.3124	17.15	.1464	14.81	797.58	6.81	.009	.48	.0041	1.59	.0086	73.2	11.55
28	11,433	13.02	108.2	6.09	2.1488	49.42	.0674	15.13	348.03	.47	.027	.63	.0009	1.49	.0496	67.4	9.15
29	3,419	11.92	322.5	8.34	.8293	58.41	.2595	16.59	1168.17	5.19	.010	.71	.0031	8.29	.0584	259.5	10.07
30	7,577	6.65	940.9	11.06	.6267	32.67	.7586	14.21	740.74	17.20	.007	.39	.0090	6.27	.0327	758.6	11.77

* A/F calculated on carbon balance from exhaust gas analysis.

Chart # 1

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O-200 ENGINE TEST DATA

FUEL : 80/87 Leaded   MAG SETTING : 18° BTDC   ENGINE HOURS : 106.3   TEST CONDITIONS : Baseline

TEST #	DATE & TIME	R.P.M	TORQUE FT. lbs	MAN. ABS. PRESS. IN HG	BARO. PRESS. IN. HG	REL. HUMY. %	INLET AIR TEMP. °F	AIR FLOW CFM	FUEL FLOW PPH	F/A RATIO OBS.	F/A RATIO COR	CYL. EXHAUST PORT TEMP °F #1	#2	#3	#4	TEMPERATURES °F OIL	CYL. HEAD	COWLING	EXH GAS	OIL PRESS PSI
31	7/29/77 10-[illegible] AM	904	22	13.19	29.72	60	87	15.1	7.7	.0920	10.51	970	910	950	840	155	205	125	685	33
32	10-30 AM	906	22	11.84	"	"	89	15.3	5.6	.0812	11.55	860	855	905	795	180	210	125	610	32
33	[illegible]	903	21	11.64	"	"	91	14.8	4.8	.0718	12.95	880	875	930	850	200	220	130	600	30.5
34	1-45 AM	1156	31	13.58	"	"	87	23.0	9.7	.0940	10.09	1010	990	1060	970	160	220	125	750	[illegible]
35	9-35 AM	1165	31	12.28	"	"	86	19.8	7.3	.0825	11.58	980	960	1050	950	185	220	130	715	32
36	9-[illegible] AM	1162	[illegible]	12.18	"	"	86	19.5	6.4	.0729	13.01	1020	995	1060	950	155	220	130	740	32.5
37	9-17 AM	1792	73	17.57	"	"	86	55.0	23.6	.0986	9.92	1240	1220	1230	1195	185	285	140	1090	35
38	9-2[illegible] AM	1785	73	17.80	"	"	87	48.4	17.5	.0817	11.57	1260	1240	1200	1230	190	290	145	1100	35
38-S	10-30 AM	1685	73	17.90			95	49.6	17.6	.07[illegible]	11.58	1260	1250	1250	12[illegible]	250	310	150	1065	31
39	[illegible]	1766	73	17.6[illegible]	"	"	87	47.4	15.5	.0775	13.01	1305	1290	1350	1295	200	305	165	1110	34.5
40	9-55 AM	1971	96	21.97	"	"	91	71.0	31.2	.0950	9.96	1270	1255	1240	1220	215	315	145	1160	35
40-S	10-42 AM	1950	96	22.14			90	75.4	32.1	.09[illegible]	9.90	1265	1245	1240	1215	180	305	140	1165	27
41	9-52 AM	1955	96	20.9[illegible]	"	"	88	69.6	25.4	.0821	11.46	1275	1260	1245	1220	200	320	145	1165	35.5
42	[illegible]	1952	96	20.7[illegible]	"	"	93	67.[illegible]	21.8	.0724	12.11	1345	1325	1380	1370	195	330	150	1240	36.5
43	10-29 AM	2755	143	28.1[illegible]	"	"	103	141.0	37.5	.0895	9.92	1500	1485	1310	1310	290	425	180	1380	33
44	10-08 AM	[illegible]	157	28.20	"		101	139.0	29.5	.0781	11.43	1560	1540	1250	1320	250	450	180	1390	34
45	10-05 AM	2754	162	[illegible]	"	"	99	137.0	[illegible]	.0606	12.05	1620	1540	1470	1470	265	450	150	1460	36.5
45-S	10-[illegible] AM	2775	162	28.3[illegible]			97	139.0	41.5	.0698	12.08	1620	1595	1455	1310	230	450	175	1465	37

Chart # 5

O-200 ENGINE EMISSION DATA

TEST #	CORRECTED CONCENTRATION				lbm/hr			lbm/1000 lbm fuel			lbm/BHP-HR			lbm/cycle/rated HP-6			A/F *
	THC ppm	CO %	NOx ppm	CO2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx ×10	
31	14,096	10.91	12.4	7.78	.4581	7.16	.0013	57.5	929.9	.17	.121	1.89	.0004	2.29	.0036	.7	7.78
32	7,495	9.63	32.1	9.07	.1958	5.08	.0028	34.9	907.7	.50	.052	1.34	.0007	.98	.0025	1.4	10.44
33	3,360	7.84	57.4	10.39	.0918	4.32	.0052	19.1	900.3	1.08	.025	1.20	.0014	.46	.0022	2.6	11.32
34	9,706	12.76	25.0	7.27	.3800	10.09	.0032	39.2	1040.0	.34	.058	1.55	.0005	5.70	.0151	4.9	9.35
35	4,669	9.29	51.0	9.23	.1607	6.88	.0058	22.0	942.2	.80	.025	1.05	.0009	2.41	.0103	8.7	10.58
36	3,145	5.64	86.1	11.50	.1080	3.91	.0098	16.9	611.4	1.53	.016	.58	.0015	1.62	.0059	14.7	12.06
37	7,134	14.04	27.1	6.91	.6744	26.91	.0085	28.6	1135.9	.36	.029	1.13	.0004	.56	.0022	.7	9.17
38	3,183	10.61	87.2	9.02	.2797	18.83	.0254	15.7	1057.6	1.43	.012	.79	.0011	.23	.0016	2.1	10.48
38-C	3,329	10.55	97.7	9.03	.2812	15.00	.0274	16.0	1022.6	1.55	.012	.76	.0012	.23	.0015	2.3	10.48
39	2,288	6.81	230.1	11.00	.2058	11.85	.0658	13.3	764.4	4.24	.009	.50	.0028	.17	.0010	5.5	11.74
40	5,914	14.50	31.4	6.80	.7388	36.58	.0130	23.7	1172.5	.42	.021	1.03	.0004	3.69	.0183	6.5	9.12
40-R	6,657	15.00	24.9	6.48	.8447	38.58	.0105	26.4	1201.9	.33	.024	1.02	.0003	4.23	.0193	5.3	8.93
41	3,532	12.31	86.9	8.13	.4348	30.60	.0355	17.1	1204.8	1.40	.012	.86	.0010	2.17	.0153	17.7	9.90
42	2,427	7.29	374.4	10.75	.2386	14.48	.2851	3.6	214.8	4.23	.007	.41	.0080	1.19	.0072	142.5	11.58
43	10,252	12.71	95.7	7.26	2.4790	62.06	.0687	43.1	1079.2	1.20	.033	.82	.0009	24.79	.0621	68.7	9.32
44	3,051	10.48	316.7	9.09	.7343	50.46	.2504	14.8	1019.3	5.06	.009	.61	.0030	7.34	.0505	250.4	10.53
45	1,759	6.32	768.4	11.28	.4691	30.57	.6103	10.8	705.9	14.09	.006	.36	.0072	4.69	.0306	616.3	11.93
45-R	2,148	6.53	764.4	11.16	.521	31.98	.6148	11.9	730.0	14.04	.006	.38	.0072	5.21	.0320	614.8	11.85

Chart # 6

* A/F calculated on carbon balance from exhaust gas analysis.

APPENDIX B2

PCV EFFECTS EVALUATION

O-200 ENGINE TEST DATA

TEST CONDITIONS: PCV
REL. HUMIDITY, BEGINNING: 60%
" " , END : 60%

FUEL: 80/87 Leaded   MAG SETTING: 28° BTDC   ENGINE HOURS: 129.30

TEST #	DATE & TIME	R.P.M	TORQUE FT. lbs	MAN. ABS. PRESS. IN. HG	BARO. PRESS. IN. HG	CRANK CASE FLOW CFM	INLET AIR TEMP. °F	AIR FLOW CFM	FUEL FLOW PPH	F/A RATIO OBS.	F/A RATIO COR	CYL. EXHAUST PORT TEMP °F #1	#2	#3	#4	TEMPERATURES °F OIL	CYL. HEAD	COWLING	EXH. GAS	OIL PRESS PSI
1	8-29-72 15.15	900	21	12.70	29.40	–	92	16.3	6.6	.0902	10.17	870	850	840	770	150	195	140	605	33.5
1-P	15.15	900	21	13.15	"	0.40	92	16.3	6.6	.0908	10.17	870	850	840	770	150	195	140	605	33.5
2	15.00	903	21	11.69	"	–	90	15.1	5.35	.0803	11.70	850	830	820	800	150	210	150	610	32.5
2-P	15.00	903	21	11.93	"	0.40	90	15.1	5.35	.0805	11.70	850	830	820	800	150	210	150	610	32.5
3	15.10	899	21	11.46	"	–	89	14.7	4.5	.0710	13.19	840	790	850	795	150	210	150	620	32
3-R	16.15	898	"	11.75			90	15.1	4.7	.0708	13.22	850	840	–	800	160	220	170	640	31
3-P	15.10	899	21	11.86	"	0.40	89	14.7	4.5	.0710	13.19	840	790	850	775	150	210	150	620	32
3-P-R	16.15	898	"	12.10		0.40	90	15.1	4.7	.0708	13.22	850	840	–	800	160	220	170	640	31
4	13.50	1104	31	13.54	"	–	86	23.9	10.0	.0938	10.05	950	980	990	960	155	220	160	760	33.5
4-P	13.50	1104	31	13.78	"	0.50	86	23.9	10.0	.0932	10.05	950	980	990	950	155	220	160	760	33.5
5	14.00	1104	31	12.60	"	–	86	21.4	7.7	.0804	11.69	980	985	960	920	155	225	160	760	33.5
5-P	14.00	1104	31	12.87	"	0.50	86	21.4	7.7	.0804	11.69	980	985	960	920	155	225	160	760	33.5
6	14.06	1104	31	12.25	"	–	86	20.7	6.5	.0715	13.19	1020	970	1000	940	155	230	160	810	33.5
6-P	14.06	1104	31	12.44	"	0.57	86	20.7	6.5	.0715	13.19	1020	970	1,000	940	155	230	160	810	33.5
7	11.10	1703	73	18.50	"	–	86	51.9	22.1	.0931	9.88	1210	1120	980	1100	160	285	190	960	36
7-P	11.10	1703	73	18.98	"	0.6	86	51.9	22.1	.0931	9.88	1210	1120	980	1100	160	285	190	960	36
8	11.15	1705	73	[illegible]	"	–	88	47.4	17.6	.0816	11.25	1260	1160	–	1130	175	300	200	1040	35
8-R	14.15	1703	72	17.50			90	49.9	19.1	.0777	11.30	1250	1150	–	1130	160	290	200	990	

CHART # 1

O-200 ENGINE EMISSION DATA

TEST #	CORRECTED CONCENTRATION				lbm/hr			lbm/1000 lbm fuel			lbm/BHP-HR			lbm/cycle/rated HP			A/F*
	THC PPM	CO %	NO_x PPM	CO_2 %	THC	CO	NO_x	THC	CO	NO_x	THC	CO	NO_x	THC	CO	NO_x	
1	20,306	11.71	3.1	6.55	.5788	6.74	.0003	87.69	1021.3	.04	.16083	1.87	.00008	289×10^{-6}	.0034	$.1 \times 10^{-6}$	9.68
1-P	19,807	11.75	3.1	6.58	.5650	6.74	.0003	85.10	1021.3	.04	.15700	1.87	.00008	282×10^{-6}	.0034	$.1 \times 10^{-6}$	9.70
2	9,992	9.58	16.7	8.65	.2824	4.70	.0013	45.31	877.7	.25	.05714	1.30	.00037	121×10^{-6}	.0023	$.7 \times 10^{-6}$	11.34
2-P	9,729	9.44	16.7	8.74	.2282	4.61	.0013	44.52	866.9	.25	.05547	1.28	.00037	119×10^{-6}	.0022	$.7 \times 10^{-6}$	11.40
3	6,020	6.28	43.2	10.70	.1488	3.14	.0035	33.07	697.3	.79	.04140	0.87	.00098	74×10^{-6}	.0016	1.2×10^{-6}	12.95
3-R	5,543	7.22	56.8	11.29	.1513	2.82	.0051	31.61	601.0	1.07	.04133	0.79	.00141	74×10^{-6}	.0014	2.5×10^{-6}	13.19
3-P	6,069	6.01	42.8	10.83	.1485	3.03	.0035	33.62	672.8	.77	.04209	0.84	.00095	76×10^{-6}	.0015	1.8×10^{-6}	13.04
3-P-R	5,332	7.23	56.9	11.29	.1427	2.82	.0051	30.26	601.0	1.07	.03060	0.79	.00141	71×10^{-6}	.0014	2.5×10^{-6}	13.21
4	17,916	12.23	3.2	6.54	.7293	10.05	.0004	72.93	1005.1	.04	.11193	1.54	.00007	365×10^{-6}	.0050	$.2 \times 10^{-6}$	9.42
4-P	17,234	12.27	3.2	6.58	.7857	10.19	.0004	70.82	1019.0	.04	.10876	1.56	.00007	354×10^{-6}	.0051	$.2 \times 10^{-6}$	9.45
5	5,017	9.29	32.8	9.29	.1761	6.58	.0045	22.87	855.1	.59	.02702	1.01	.00069	264×10^{-6}	.0099	6.8×10^{-6}	11.39
5-P	4,706	9.16	29.4	9.39	.1675	6.58	.0046	21.75	855.1	.60	.02571	1.01	.00071	251×10^{-6}	.0099	7.0×10^{-6}	11.43
6	3,070	6.44	76.4	10.91	.1149	4.87	.0095	17.67	738.7	1.46	.01766	.75	.00146	172×10^{-6}	.0073	14.2×10^{-6}	12.50
6-P	3,059	6.32	76.2	10.98	.1149	4.77	.0095	17.67	736.6	1.46	.01766	.74	.00146	172×10^{-6}	.0072	14.2×10^{-6}	12.53
7	8,578	13.11	19.3	7.03	.7174	22.13	.0054	32.47	1001.5	.24	.03021	.94	.00023	60×10^{-6}	.0018	$.4 \times 10^{-6}$	9.73
7-P	8,444	13.07	19.3	7.07	.7086	22.13	.0054	32.07	1001.8	.24	.02994	.94	.00023	59×10^{-6}	.0018	$.4 \times 10^{-6}$	9.66
8	4,167	10.40	69.6	4.02	.3263	15.73	.0171	18.54	897.2	1.02	.01277	.66	.00076	27×10^{-6}	.0013	1.5×10^{-6}	10.95
8-R	4,158	10.59	70.8	3.77	.3526	18.15	.0270	19.54	1069.2	1.12	.01474	.77	.00079	29×10^{-6}	.0015	1.7×10^{-6}	10.69

* A/F calculated on carbon balance from exhaust gas analysis.

CHART # 2

O-200 ENGINE TEST DATA

TEST CONDITIONS: PCV
REL. HUMIDITY, BEGINNING: 60%
" " , END : 60%

FUEL: 80/87. Leaded MAG SETTING: 28° BTDC ENGINE HOURS: 129.30

TEST #	DATE & TIME	R.P.M	TORQUE	MAN. ABS. PRESS.	BARO. PRESS.	CRANK CASE FLOW	INLET AIR TEMP. °F	AIR FLOW	FUEL FLOW	F/A RATIO		CYL. EXHAUST PORT TEMP °F				TEMPERATURES °F				OIL
			FT. lbs	IN HG	IN. HG	C.F.M		CFM	PPH	OBS.	COR	# 1	# 2	# 3	# 4	OIL	CYL. HEAD	COWLING	EXH. GAS	PRESS PSI
8-P	11.15	1705	73	17.48	29.40	0.6	88	47.4	17.6	.0816	11.25	1260	1110	—	1140	175	300	200	1240	37
8-P.2	14.15	1703	73	18.28		0.61	90	49.8	18.1	.0797	11.30	1250	1160	—	1120	160	290	250	990	36
9	11.20	1702	73	17.16	"	—	89	46.0	14.6	.0704	13.11	1260	1250	—	1225	190	320	210	1050	34.5
9-P	14.20	1702	73	17.71	"	0.57	89	46.0	14.6	.0704	13.11	1260	1250	-	1225	190	320	210	1050	34.5
10	14.25	1954	96	21.30	"	—	94	71.6	29.5	.0905	9.92	1280	1190	—	1160	180	290	210	1000	26
10-P	14.25	1954	96	21.69	"	0.80	94	71.6	29.5	.0905	9.92	1280	1190	—	1160	180	290	210	1,000	26
11	14.30	1952	96	19.94	"	—	96	65.8	23.5	.0789	11.37	1320	1240	—	1210	205	325	230	1060	35
11-P	14.30	1952	96	20.20	"	0.77	96	65.8	23.5	.0789	11.37	1320	1240	—	1210	205	325	230	1060	35
12	14.35	1937	96	19.82	"	—	98	65.6	20.1	.0681	13.15	1400	1220	—	1280	220	350	240	1120	34
12-P	14.35	1937	96	20.04	"	0.77	98	65.6	20.1	.0681	13.15	1400	1320	—	1250	220	350	240	1120	34
13	11.50	2747	158	28.23	"	—	98	140.0	57.7	.0900	9.18	1460	1380	1220	1350	190	400	250	1240	40
13-P	14.30	2745	158	28.23			104	142.0	56.5	.0872	9.65	1470	1390	—	1355	240	410	270	1070	37
13-P	11.50	2747	158	28.27	"	1.85	98	140.0	57.7	.0900	9.78	1460	1250	1220	1350	190	400	260	1090	40
13-P.2	14.40	2745	158	28.20		1.84	104	142.3	56.5	.0572	9.65	1470	1390	—	1355	240	410	270	1090	37
14	12.05	2750	162	28.23	"	—	104	140.0	48.3	.0763	11.43	1520	1430	—	1395	230	435	280	1160	32
14-P	12.05	2750	162	28.23	"	1.85	104	140.0	48.3	.0763	11.43	1520	1430	—	1395	230	435	280	1160	32
15	12.10	2747	165	28.23	"	—	108	139.0	42.3	.0665	12.76	1550	1500	—	1470	230	460	210	1250	30
15-P	12.10	2747	165	28.23	"	2.0	108	139.0	42.3	.0665	12.76	1550	1500	—	1470	230	460	290	1260	30

CHART # 3

O-200 ENGINE EMISSION DATA

TEST #	CORRECTED CONCENTRATION				lbm/hr			lbm/1000 lbm fuel			lbm/BHP-HR			lbm/cycle/rated HP			A/F *
	THC PPM	CO %	NOx PPM	CO_2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	
8-P	4,163	[illegible]	69.6	9.02	.3236	15.70	.0179	18.39	872.2	1.02	.01404	.68	.00078	27×10^{-6}	.0013	1.5×10^{-6}	10.93
8-P-E	4,034	10.59	74.1	8.73	.3481	18.18	.0200	19.23	1034.2	1.15	.01470	.77	.00084	29×10^{-6}	.0015	1.7×10^{-6}	10.70
9	2,390	6.23	307.9	11.03	.2005	10.73	.0855	13.73	739.9	5.89	.00548	.45	.00261	17×10^{-6}	.0009	7.1×10^{-6}	12.27
9-P	2,547	7.25	252.2	10.56	.2108	12.11	.0692	14.44	829.7	4.74	.00891	.51	.00293	18×10^{-6}	.0010	5.8×10^{-6}	12.31
10	6,425	13.24	28.7	7.18	.7296	30.36	.0108	24.73	1029.1	.37	.02042	.85	.00030	365×10^{-6}	.0152	5.4×10^{-6}	9.67
10-P	6,759	13.35	27.1	7.09	.7657	30.49	.0102	25.93	1055.6	.35	.02144	.85	.00028	383×10^{-6}	.0152	5.1×10^{-6}	9.62
11	3,815	9.84	97.0	9.15	.4145	21.54	.0349	17.69	916.6	1.29	.01162	.60	.00098	207×10^{-6}	.0108	17.5×10^{-6}	10.94
11-P	3,757	9.79	98.3	9.17	.4073	21.42	.0353	17.33	911.6	1.50	.01141	.60	.00099	204×10^{-6}	.0107	17.7×10^{-6}	10.96
12	2,305	6.57	376.7	10.92	.2690	15.53	.1461	13.42	772.5	7.27	.00758	.44	.00411	135×10^{-6}	.0078	73.1×10^{-6}	12.13
12-P	2,297	6.55	365.8	10.88	.2697	15.77	.1424	13.42	784.0	7.08	.00758	.44	.00400	135×10^{-6}	.0079	71.2×10^{-6}	12.10
13	6,760	[illegible]	101.0	7.67	1.4901	54.62	.0742	25.08	946.6	1.79	.01514	.66	.00090	1499×10^{-6}	.0546	74.3 $\times 10^{-6}$	9.85
13-E	7,058	11.94	114.0	7.77	1.5565	53.16	.0834	26.84	916.6	1.44	.01555	.64	.00101	1556×10^{-6}	.0532	83.4	9.91
13-P	9,558	11.95	92.4	7.51	2.1626	54.62	.0694	37.50	946.6	1.20	.02618	.66	.00084	2164×10^{-6}	.0546	69.4 $\times 10^{-6}$	9.71
13-P-E	8,498	11.91	96.6	7.63	1.8939	53.16	.0729	32.65	916.6	1.26	.02292	.64	.00088	1894×10^{-6}	.0532	72.9	9.84
14	2,431	10.67	240.4	8.86	.6046	53.59	.1983	12.52	1109.5	4.10	.00713	.63	.00234	605×10^{-6}	.0536	198.3×10^{-6}	10.61
14-P	2,622	11.09	202.8	8.68	.6359	55.11	.1665	13.37	1140.9	3.45	.00761	.65	.00196	646×10^{-6}	.0551	166.5×10^{-6}	10.47
15	2,023	6.49	629.8	10.99	.4908	31.82	.5068	11.60	752.2	11.98	[illegible]	.37	.00587	491×10^{-6}	.0318	506.5×10^{-6}	12.01
15-P	[illegible]	6.75	514.2	10.87	.4615	[illegible]	.4198	12.92	775.3	9.71	[illegible]	[illegible]	.00476	462×10^{-6}	.0319	[illegible]	11.87

* A/F calculated on carbon balance from exhaust gas analysis.

CHART # 4

O-200 ENGINE TEST DATA

TEST CONDITIONS: PCV
REL. HUMIDITY, BEGINNING : 60 %
" " , END : 60 %

FUEL : 80/87 Leaded MAG SETTING : 23° BTDC. ENGINE HOURS : 125.0

TEST #	DATE & TIME	R.P.M	TORQUE FT. lbs	MAN. ABS. PRESS. IN HG	BARO. PRESS. IN. HG	CRANK CASE FLOW CFM	INLET AIR TEMP. °F	AIR FLOW CFM	FUEL FLOW PPH	F/A RATIO		CYL. EXHAUST PORT TEMP. °F				TEMPERATURES °F				OIL
										OBS.	COR. A/F	# 1	# 2	# 3	# 4	OIL	CYL. HEAD	COWLING	EXH. GAS	PRESS PSI
16	8/24/72 14.05	903	21	11.69	29.30	—	89	15.1	4.7	.0765	13.22	900	890	920	880	170	220	165	700	31.5
16-P	14.05	903	21	11.89	"	0.37	89	15.1	4.7	.0765	13.22	900	890	920	880	170	220	165	700	31.5
17	12.03	1705	73	17.76	"	—	98	49.5	17.3	.0779	11.50	1300	1225	1245	1200	170	290	200	1050	35.5
17-P	12.03	1705	73	18.07	"	0.60	98	49.5	17.3	.0779	11.50	1300	1225	1245	1200	170	290	200	1050	35.5
18	14.28	2750	156	28.11	"	—	103	143.0	57.2	.0875	9.86	1540	1370	1265	1340	195	395	260	1140	37.5
18-P	14.28	2750	156	28.11	"	1.47	103	143.0	57.2	.0875	9.86	1540	1370	1265	1340	195	395	260	1140	37.5

CHART # 5

O-200 ENGINE EMISSION DATA

TEST #	CORRECTED CONCENTRATION				lbm/hr			lbm/1000 lbm fuel			lbm/BHP-HR			lbm/cycle/rated HP			A/F
	THC PPM	CO %	NOx PPM	CO2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	
16	5,233	6.70	39.1	10.53	.1376	3.56	.0034	29.78	757.1	.73	.03811	.99	.00096	59×10^{-6}	.0016	1.7×10^{-6}	12.75
16-P	4,905	6.58	39.0	10.62	.1292	3.50	.0036	27.49	745.1	.73	.03579	.97	.00094	65×10^{-6}	.0015	1.7×10^{-6}	12.82
17	3,251	9.07	78.0	9.53	.2665	14.57	.0206	15.41	842.3	1.19	.01125	.61	.00087	22×10^{-6}	.0012	1.7×10^{-6}	11.03
17-P	3,268	9.07	77.0	9.53	.2679	14.57	.0203	15.48	842.1	1.17	.01130	.61	.00086	22×10^{-5}	.0012	1.7×10^{-6}	11.03
18	9,567	11.27	50.4	7.81	2.2409	53.32	.0392	39.18	932.1	.68	.02745	.65	.00048	.002241	.0533	39.2×10^{-6}	10.03
18-P	8,858	11.13	47.7	7.91	2.0090	50.97	.0372	33.12	991.2	.63	.02461	.62	.00044	.002009	.0510	35.0×10^{-6}	10.05

* A/F calculated on carbon balance from exhaust gas analysis.

CHART # 6

O-200 ENGINE TEST DATA

TEST CONDITIONS: PCV

FUEL: 80/87 Leaded MAG SETTING: 18° BTDC ENGINE HOURS: 129.30

REL. HUMIDITY, BEGINNING: 60%

" " , END: 60%

TEST #	DATE & TIME	R.P.M	TORQUE FT. lbs	MAN. ABS. PRESS. IN HG	BARO. PRESS. IN. HG	CRANK CASE FLOW CFM	INLET AIR TEMP. °F	AIR FLOW CFM	FUEL FLOW PPH	F/A RATIO		CYL. EXHAUST PORT TEMP °F				TEMPERATURES °F				OIL
										OBS.	COR.	#1	#2	#3	#4	OIL	CYL. HEAD	COWLING	EXH. GAS	PRESS PSI
19	9-29-72 15.50	899	21	11.77	29.40	—	90	15.6	4.8	.0705	13.18	955	880	910	860	165	225	160	660	31
19-P	15.50	899	21	11.93	"	0.40	90	15.6	4.8	.0705	13.18	955	880	910	860	165	225	160	660	31
20	15.40	1703	73	18.35	"	—	90	52.6	19.1	.0801	11.42	1350	1245	—	1220	160	295	200	1060	36
20-P	15.40	1703	73	13.95	"	0.60	90	52.6	19.1	.0801	11.42	1350	1245	—	1220	160	295	200	1060	36
21	16.00	2754	149	28.21	"	—	100	144	58.1	.0885	9.02	1590	1470	—	1420	190	370	250	1220	40
21-P	16.00	2754	149	38.31	"	1.52	100	144	58.1	.0885	9.92	1590	1470	—	1420	190	370	250	1220	40

CHART # 7

O-200 ENGINE EMISSION DATA

TEST *	CORRECTED CONCENTRATION				lbm/hr			lbm/1000 lbm fuel			lbm/BHP-HR			lbm/cycle/rated HP			A/F
	THC ppm	CO %	NOx ppm	CO_2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	
19	4,447	6.03	41.2	10.95	.1160	3.21	.0036	24.17	667.8	.74	.03081	.85	.00095	58×10^{-6}	.0016	1.8×10^{-6}	13.00
19-P	4,543	6.08	38.0	10.95	.1186	3.21	.0033	24.71	667.8	.69	.03150	.85	.00087	59×10^{-6}	.0016	1.6×10^{-6}	13.00
20	3,793	11.12	58.3	8.50	.3444	20.32	.0172	18.03	1067.2	.92	.01455	.86	.00074	29×10^{-6}	.0017	1.5×10^{-6}	11.03
20-P	3,701	11.04	60.0	8.55	.3384	20.32	.0182	17.72	1067.2	.95	.01430	.86	[illegible]	22×10^{-6}	.0017	1.5×10^{-6}	11.06
21	10,446	11.51	53.6	7.64	2.4455	54.43	.0417	42.09	936.9	.72	.03120	.70	.00053	.002446	.0544	41.7×10^{-6}	9.71
21-P	12,504	11.24	39.8	7.57	2.9770	54.43	.0317	51.60	936.9	.54	.03577	.70	.00041	.002978	.0544	31.7×10^{-6}	9.63

* A/F calculated on carbon balance from exhaust gas analysis.

CHART # 8

APPENDIX B3

SECONDARY-AIR INJECTION EVALUATION

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 167.8 / 171.3

0-200 ENGINE TEST DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
1-1	10 45	903	21	12.88	900	10:1	–	17.2	75	–	–	0.1	7.2	10.36	240	200	255	230	140	405	125	410	34.0
1-2	"	"	"	"	"	"	90	"	"	5.2	75	0.4	"	13.57	245	205	260	235	140	390	125	420	34.0
1-3	"	"	"	"	"	"	100	"	"	7.8	75	0.7	"	15.45	245	205	260	235	140	380	125	420	34.0
1-4	"	"	"	"	"	"	110	"	"	10.2	75	1.2	"	16.86	245	205	260	235	135	375	125	415	34.0
2-1	1035	903	"	12.25	"	11.5:1	–	15.4	76	–	–	0.1	5.55	11.69	250	210	265	240	155	380	130	385	33.5
2-2	"	"	"	"	"	"	90	"	"	2.5	87	0.1	"	13.90	250	210	265	240	155	380	130	395	32.5
2-3	"	"	"	"	"	"	100	"	"	4.3	85	0.2	"	15.34	250	210	260	240	150	380	125	400	33.5
2-4	"	"	"	"	"	"	110	"	"	6.1	85	0.5	"	16.79	240	205	260	235	150	380	125	410	34.0
3-1	1020	904	"	11.54	"	13:1	–	15.0	80	–	–	0.1	4.85	13.19	265	225	285	250	160	400	140	410	32.0
3-2	"	"	"	"	"	"	90	"	"	0.5	82	0.1	"	13.64	260	220	280	255	145	395	140	410	33.0
3-3	"	"	"	"	"	"	100	"	"	2.1	82	0.1	"	15.35	260	220	280	255	145	395	140	410	33.0
3-4	"	"	"	"	"	"	110	"	"	3.6	82	0.1	"	16.46	260	220	280	255	145	395	140	410	33.0
4-1	1125	1102	31	13.03	1100	10:1	–	22.7	76	–	–	0.1	9.45	10.38	270	225	285	250	150	470	135	490	34.5
4-2	"	"	"	"	"	"	90	"	"	7.5	80	0.7	"	14.07	270	225	285	250	150	450	135	500	34.5
4-3	"	"	"	"	"	"	100	"	"	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 167.2 / 171.3

0-200 ENGINE EMISSION DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60 % / 60 %
BARO. PRESSURE: 29.70 / 29.70 IN HG

RUN NO	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOX PPM	CO2 %	O2 %	THC	CO	NOX	THC	CO	NOX	THC	CO	NOX	THC	CO	NOX
1-1	903	10.0	10.36	9.5	20,060	10.15	9.9	7.26	2.15	0.592	6.05	.001	82.21	840	0.13	.164	1.67	.0003	.1184	1.21	.0002
1-2	"	13.2	13.57	12.8	16,260	10.84	10.6	7.30	5.5	0.519	6.99	.0011	72.10	971	0.16	.144	1.94	.0003	.1038	1.392	.00022
1-3	"	14.7	15.45	14.7	15,670	10.45	9.2	7.55	6.3	0.474	6.32	.0009	65.21	886	0.13	.131	1.77	.00025	.0948	1.276	.00018
1-4	"	16.2	16.86	16.1	15,920	11.18	8.6	7.21	7.5	0.446	6.53	.0008	61.92	907	0.11	.123	1.81	.0002	.0892	1.306	.00016
2-1	903	11.5	11.69	11.8	7,130	9.61	22.7	8.82	2.5	0.190	5.17	.0020	33.87	923	0.36	.053	1.43	.00055	.032	1.024	.0004
2-2	"	13.2	13.90	13.2	6,510	9.76	23.3	8.81	3.9	0.166	5.03	.0020	29.64	898	0.35	.046	1.39	.00055	.0332	1.006	.0004
2-3	"	14.7	15.34	14.2	6,430	9.49	23.4	8.95	4.5	0.158	4.70	.0019	28.17	840	0.34	.044	1.31	.0005	.0316	.94	.00028
2-4	"	16.2	16.79	15.9	6,240	9.48	22.3	8.98	6.2	0.152	4.65	.0018	27.07	831	0.32	.042	1.29	.0005	.0304	.93	.00036
3-1	904	13.0	13.19	13.3	4010	5.92	61.7	10.98	2.4	0.107	3.18	.0054	21.95	656	1.12	.030	0.88	.0015	.0214	.636	.00108
3-2	"	13.2	13.69	14.0	3,810	5.54	57.3	11.19	3.1	0.098	2.86	.0049	20.05	589	1.00	.027	0.79	.0014	.0196	.572	.00095
3-3	"	14.7	15.05	15.2	3,670	5.33	58.4	11.31	4.2	0.091	2.65	.0048	18.62	547	0.98	.025	0.74	.0013	.0182	.53	.0009
3-4	"	16.2	16.46	16.7	3,770	5.47	63.5	11.23	5.5	0.083	2.57	.0049	18.12	531	1.01	.024	0.71	.0014	.0176	.514	.00098
4-1	1102	10.0	10.38	10.6	12990	10.91	13.6	7.59	1.85	0.49	8.31	.0017	51.84	880	0.18	.076	1.28	.00025	.0327	.554	.00011
4-2	"	13.2	14.07	13.3	9,790	11.50	13.36	7.61	4.7	.372	8.81	.0017	39.3	932	0.18	.057	1.35	.0026	.0248	.587	.00112
4-3	"	14.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 167.8 / 171.3

0-200 ENGINE TEST DATA

DATE : Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CCKE	COWLING	EXH. GAS	
4-4	1125	1102	31	13.03	1100	10:1	110	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1115	1101	"	12.80	"	11.5:1	—	21.2	76	—	—	0.1	8.0	11.46	285	240	295	265	150	450	140	475	34.5
5-2	"	"	"	"	"	"	90	"	"	3.2	80	0.15	"	13.25	285	240	295	265	145	450	140	485	34.5
5-3	"	"	"	"	"	"	100	"	"	6.2	80	0.5	"	15.05	285	240	295	265	150	440	140	485	34.5
5-4	"	"	"	"	"	"	110	"	"	8.7	80	0.7	"	16.46	285	240	295	265	150	440	140	485	34.5
6-1	1105	1100	"	12.93	"	13:1	—	21.3	76	—	—	0.1	6.95	13.25	285	240	305	270	140	475	140	495	35.0
6-2	"	"	"	"	"	"	90	"	"	0.5	80	0.1	"	13.57	285	240	305	270	145	475	140	495	35.0
6-3	"	"	"	"	"	"	100	"	"	2.8	80	0.1	"	15.05	285	240	305	270	145	465	140	490	34.5
6-4	"	"	"	"	"	"	110	"	"	5.9	80	0.4	"	17.11	285	240	305	270	145	450	140	495	34.5
7-1	1005	1702	73	19.25	1700	10:1	—	54.0	84	—	—	0.5	22.2	9.96	380	320	390	340	180	725	145	825	34.0
7-2	"	"	"	"	"	"	90	"	"	15.0	115	1.2	"	13.03	370	315	380	350	175	670	140	750	34.5
7-3	"	"	"	"	"	"	100	"	"	25.0	125	1.6	"	15.20	370	315	385	340	175	1300	145	1590	35.0
7-4	"	"	"	"	"	"	110	"	"	30.0	140	3.5	"	16.39	380	320	375	350	175	1430	150	1730	34.5
8-1	950	1702	"	18.58	"	11.5:1	—	50.4	84	—	—	0.5	19.35	11.55	415	335	420	390	175	770	160	855	34.0
8-1-R	1150	1702		18.74				51.6	82				19.0	11.50	390	325	405	365	165	750	170	845	36.5
8-2	950	"	"	18.58	"	"	90	50.4	84	9.0	105	0.7	18.35	13.77	415	325	420	390	175	770	160	860	34.0
8-2-R	1150			18.74				51.6	82	9.0	95	0.7	19.0	13.16	390	330	410	370	175	735	170	825	36.0

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 167.8 / 171.3

0-200 ENGINE EMISSION DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR.	C.B.	THC PPM-C	Co %	NOX PPM	CO_2 %	O_2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
4-4	1102	16.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1101	11.5	11.46	11.6	4020	10.48	39.4	8.7	2.1	0.15	7.89	.005	18.7	986	.61	.023	1.21	.00075	.010	.526	.00032
5-2	″	13.2	13.25	13.4	4,030	10.33	39.5	8.78	4.5	.148	7.65	.0048	18.48	957	.60	.023	1.18	.00074	.0099	.510	.00032
5-3	″	14.7	15.05	15.0	3,990	10.26	38.6	8.81	6.2	.146	7.56	.0047	18.20	946	.58	.0224	1.165	.00072	.0097	.504	.000312
5-4	″	16.2	16.46	16.2	3,950	10.34	38.9	8.78	7.2	.144	7.59	.0047	17.94	949	.59	.022	1.17	.00072	.0096	.506	.000312
6-1	1100	13.0	13.25	13.1	2,730	6.49	124	10.82	2.2	.104	4.99	.0156	14.93	718	2.25	.016	.77	.0024	.0069	.333	.00104
6-2	″	13.2	13.57	13.6	2,700	6.27	119.7	10.98	2.8	.100	4.67	.0146	14.33	672	2.11	.0155	.72	.0023	.0067	.311	.00097
6-3	″	14.7	15.05	15.1	2,550	6.03	94	11.07	4.6	.095	4.54	.0116	13.67	654	1.67	.015	.70	.0018	.0063	.303	.00077
6-4	″	16.2	17.11	16.5	2,250	6.09	90	11.07	5.8	.083	4.53	.011	11.87	651	1.58	.012	.70	.0017	.0055	.302	.00073
7-1	1702	10.0	9.96	9.8	6,750	12.83	27	7.46	.35	.59	22.0	.008	25.92	964	.35	.025	.93	.00033	.0049	.813	.00006
7-2	″	13.2	13.03	12.6	6,040	13.55	25	6.97	4.5	.52	23.5	.0072	22.77	1032	.31	.022	.99	.0003	.0043	.196	.00005
7-3	″	14.7	15.20	16.3	470	4.06	31.4	12.27	.7	.0752	13.2	.017	3.3	580	.74	.0032	.56	.0007	.00062	.110	.00014
7-4	″	16.2	16.39	15.1	22	1.28	29.5	13.70	1.8	.0037	4.69	.0235	.16	204	1.03	.0002	.20	.001	.00003	.0387	.00019
8-1	1702	11.5	11.55	11.3	3,060	10.15	123	8.96	.7	.297	19.89	.04	16.18	1084	2.16	.0126	.84	.0017	.00247	.166	.00033
8-1-R	1702		11.50	11.32	3,070	10.47	95	8.80	1.6	.291	20.01	.03	15.33	1054	1.57	.0122	.85	.0013	.00242	.167	.00024
8-2	″	13.2	13.77	13.3	2,500	9.40	118	9.40	4.05	.24	18.16	.037	13.09	990	2.04	.0101	.77	.0016	.0020	.151	.0003
8-2-R			13.66	13.5	2,950	10.46	85	8.82	4.8	.27	19.37	.026	14.73	1020	1.35	.0119	.82	.0011	.0022	.161	.00021

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 167.8 / 171.3

0-200 ENGINE TEST DATA

DATE : Oct 7, 1972
REL. HUMIDITY: 60 % / 60 %
BARO. PRESSURE: 29.20 / 29.20 IN HG.

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP, °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
8-3	900	1702	73	18.53	1700	11.5:1	100	50.4	84	15.0	115	1.0	18.35	15.37	405	335	420	335	180	825	160	1355	31.0
8-3-R	1150	1702		18.74				51.6	82	15.0	105	1.1	19.0	15.23	390	320	410	370	185	1180	170	1400	36.0
8-4	950	"	"	18.58	"	"	110	50.4	84	20.0	125	1.6	18.35	16.60	405	325	420	385	180	1230	160	1520	34.0
8-4-2	1150			18.74				51.6	82	20.0	120	1.7	19.0	16.42	390	320	410	370	190	1300	170	1540	35.5
9-1	935	1703	"	18.35	"	13:1	-	48.9	82	-	-	0.4	16.0	12.95	410	345	420	395	180	795	155	890	35.5
9-2	"	"	"	"	"	"	90	"	"	1.5	82	0.45	"	13.36	410	340	430	400	170	790	155	880	36.0
9-3	"	"	"	"	"	"	100	"	"	6.15	85	0.7	"	14.97	415	340	435	395	170	800	155	980	35.5
9-4	"	"	"	"	"	"	110	"	"	14.0	115	1.2	"	16.51	415	340	430	405	175	1160	155	1420	35.0
10-1	1225	1955	96	22.12	1950	10:1	-	75.1	90	-	-	0.7	31.0	9.98	420	350	440	420	195	840	180	925	33.0
10-2	"	"	"	"	"	"	90	*	"	*	*	*	"	*	*	*	*	*	*	*	*	*	*
10-3	"	"	"	"	"	"	100	"	"	24.0	150	3.8	"	14.09	415	345	430	415	200	1430	180	1740	33.5
10-4	"	"	"	"	"	"	110	"	"	32.0	170	3.8	"	15.46	420	360	435	420	200	1500	180	1790	33.5
11-1	1215	1945	96	21.50	"	11.5:1	-	71.0	90	-	-	0.6	25.6	11.42	440	370	470	450	200	860	180	955	33.0
11-2	"	"	"	"	"	"	90	"	"	12.5	120	1.1	"	13.64	440	370	470	440	200	870	180	970	33.0
11-3	"	"	"	"	"	"	100	"	"	20.0	130	1.8	"	15.13	430	370	470	440	200	1260	180	1500	33.0
11-4	"	"	"	"	"	"	110	"	"	25.0	145	3.2	"	16.25	430	370	470	410	200	1380	180	1670	33.0
12-1	1200	1952	"	21.41	"	13:1	-	70.1	88	-	-	0.6	22.3	13.04	455	380	495	455	180	900	195	1010	35.0

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 167.8 / 171.3

0-200 ENGINE EMISSION DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60 % / 60 %
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B.	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
8-3	1702	14.7	15.37	14.9	373	2.78	105	12.91	.85	.047	7.05	.0434	2.55	384	2.37	.002	.3	.0018	.00029	.0587	.00026
8-3-R			15.23		315	2.76	80	12.93	.50	.041	7.24	.0346	2.14	381	1.82	.0017	.31	.0015	.00074	.0667	.00022
8-4	"	16.2	16.60	15.4	18	.55	71	14.07	1.75	.0025	1.52	.0326	.13	83	1.78	.0001	.064	.0014	.00002	.0127	.00027
8-4-R			16.43		35	.78	59	13.95	1.55	.005	2.30	.0254	.27	121	1.50	.0002	.097	.0012	.00004	.0191	.00022
9-1	1703	13.0	12.95	12.2	2,351	6.21	363	11.01	.4	.2145	11.63	.112	13.41	727	7	.009	.49	.0047	.00178	.0969	.00023
9-2	"	13.2	13.36	12.7	2,205	6.3	331	10.97	.75	.201	11.57	.10	12.53	723	6.3	.0085	.49	.0042	.00167	.0964	.00083
9-3	"	14.7	14.99	14.9	1,375	5.33	323	11.29	4.45	.131	11.19	.102	8.16	699	6.4	.0055	.47	.0043	.00109	.0932	.00084
9-4	"	16.2	16.51	16.0	21	.5	277	14.09	2.5	.0025	1.18	.108	.15	74	6.7	.0001	.05	.0045	.00002	.0098	.0009
10-1	1955	10.0	9.98	9.7	5,590	13.3	31	7.13	0.5	.652	21.36	.052	21.1	1012	.49	.0183	.88	.00042	.0652	3.136	.00152
10-2	"	13.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
10-3	"	14.7	14.09	14.5	265	3.33	38	12.65	.65	.0523	13.3	.025	1.69	429	.81	.0015	.372	.0007	.0052	1.33	.0025
10-4	"	16.2	15.46	15.3	27	1.41	45	13.63	1.65	.0057	5.92	.036	.18	191	1.01	.0002	.166	.0009	.00057	.592	.036
11-1	1945	11.5	11.42	11.3	3,150	9.00	116	9.53	.65	.394	22.8	.0483	15.39	890	1.89	.0111	.64	.0014	.0394	2.28	.00483
11-2	"	13.2	13.64	12.7	2,035	5.38	84	11.44	.80	.331	17.3	.0443	12.94	675	1.73	.0093	.49	.0013	.0331	1.73	.0044
11-3	"	14.7	15.13	14.1	160	2.79	73	12.93	.95	.029	10.29	.0441	1.13	402	1.72	.0008	.29	.0013	.0029	1.03	.0044
11-4	"	16.2	16.25	15.2	21	0.90	72	13.29	2.15	.004	3.38	.0442	.15	132	1.73	.0001	.095	.0013	.0004	.338	.0044
12-1	1952	13.0	13.04	12.3	2,040	5.86	560	11.21	.4	.258	14.99	.225	11.57	672	10.55	.0072	.42	.0066	.0258	1.49	.0225

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 22° BTDC
ENGINE HRS: [illegible].8 / 171.3

O-200 ENGINE TEST DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 in HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
12-2	1200	1952	96	21.41	1950	13:1	90	70.1	88	4.0	120	1.1	22.3	13.86	460	385	495	460	185	950	185	1080	35
12-3	″	″	″	″	″	″	100	″	″	9.0	115	1.2	″	14.90	460	385	495	460	195	1170	185	1380	34.5
12-4	″	″	″	″	″	″	110	″	″	15.0	125	1.7	″	16.23	465	390	500	460	195	1240	185	1460	33.5
13-1	1250	2745	137	28.11	2750	10:1	–	141.0	103	–	–	1.8	55.6	9.97	590	490	550	590	265	1010	230	1150	30.5
13-2	″	″	120	″	″	″	90	″	″	40.0	200	3.8	″	13.34	600	480	535	595	265	1500	240	1810	30.5
13-3	–	–	–	–	″	″	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	″	″	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	1245	2750	145	28.11	″	11.5:1	–	139.1	100	–	–	1.7	48.5	11.40	600	495	610	550	255	1060	225	1210	31.0
14-2	″	″	140	″	″	″	90	″	″	20.0	165	3.2	″	13.44	595	490	610	555	260	1215	230	1450	31.0
14-3	″	″	135	″	″	″	100	″	″	34.0	180	3.8	″	14.99	600	490	610	550	260	1470	235	1740	31.0
14-4	–	–	–	–	″	″	110	″	″	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1235	2745	150	28.11	″	13:1	–	138.8	100	–	–	1.8	42.7	12.92	585	490	630	580	220	1110	225	1270	34.5
15-2	″	″	145	″	″	″	90	″	″	6.0	130	2.2	″	13.57	590	500	645	590	235	1160	225	1350	33.0
15-3	″	″	140	″	″	″	100	″	″	18.0	150	3.3	″	15.02	600	500	650	600	240	1300	230	1520	31.5
15-4	″	″	135	″	″	″	110	″	″	29.0	180	3.7	″	16.40	600	500	[illegible]	600	250	1450	235	1660	31.5

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 28° BTDC
ENGINE LBS: 167.8 / 171.3

0-200 ENGINE EMISSION DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
12-2	1952	13.2	13.86	12.7	990	4.9	425	11.80	.35	.136	13.59	.194	6.10	610	8.7	.0038	.381	.0054	.0136	1.359	.0194
12-3	"	14.7	14.90	14.2	82	1.85	358	13.41	.5	.0123	5.60	.178	.55	251	8.0	.00034	.157	.005	.00123	.56	.0178
12-4	"	16.2	16.23	15.3	18	.82	225	13.90	1.8	.0023	2.85	.119	.13	128	5.4	.00008	.080	.0033	.00023	.285	.0117
13-1	2745	10.0	9.97	9.9	5,190	12.56	91	7.55	.5	1.14	55.7	.0665	20.5	1001	1.20	.016	.78	.0009	.0057 .0950	.279 4.64	.0022 .0055
13-2	"	13.2	13.34	12.9	1420	4.54	69	11.93	.5	.51	32.8	.0815	9.1	590	1.47	.008	.52	.0013	.0025 .0425	.164 2.73	.0004 .0068
13-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-4	-	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-1	2750	11.5	11.40	10.8	2230	10.7	180	8.77	.55	.55	53.1	.147	11.32	1097	3.03	.007	.70	.0019	.0027 .046	.26 4.43	.00073 .012
14-2	"	13.2	13.44	12.9	660	7.36	136	10.6	.45	.192	43.5	.132	3.96	897	2.72	.0026	.59	.0018	.00096 .0160	.22 3.62	.0007 .011
14-3	"	14.7	14.99	14.4	60	1.69	180	13.69	.90	.019	11.0	.192	.39	226	3.96	.0003	.16	.0027	.00009 .00154	.055 .917	.0009 .016
14-4	-	16.2	-	-	-	-	-	-	1.85	-	-	-	-	-	-	-	-	-	-	-	-
15-1	2745	13.0	12.92	12.4	1480	5.92	570	11.24	.5	.364	29.5	.466	8.51	690	10.92	.005	.38	.006	.0018 .03	.148 2.46	.0023 .39
15-2	"	13.2	13.57	12.7	540	5.30	497	11.64	.5	.140	27.7	.426	3.27	648	9.97	.002	.37	.0056	.0007 .117	.138 2.31	.0021 .035
15-3	"	14.7	15.02	14.4	310	3.31	456	12.66	.85	.089	19.3	.437	2.08	453	10.23	.0012	.264	.006	.0004 .0074	.0965 1.61	.0022 .036
15-4	"	16.7	16.40	16.1	15	.21	463	14.24	2.4	.0026	1.2	.441	.09	29	10.32	.00005	.017	.0063	.00001 .0003	.006 .1	.0022 .037

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 171.3 / 174.7

0-200 ENGINE TEST DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG.

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
1-1	1615	905	21	12.87	900	10:1	-	16.1	78	-	-	0.1	6.65	10.47	250	210	265	245	130	415	130	415	34.0
1-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-4	1615	905	21	12.87	"	"	110	16.1	78	8.0	85	1.2	6.65	16.69	250	210	265	245	130	390	130	430	34.0
2-1	1610	906	21	12.48	"	15:1	-	15.5	78	-	-	0.1	5.65	11.78	260	220	270	250	130	410	135	430	34.0
2-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-4	1610	906	21	12.48	"	"	110	15.5	78	6.5	85	0.5	5.65	17.0	260	215	270	250	130	405	135	415	34.0
3-1	1600	904	21	12.40	"	13:1	-	15.5	77	-	-	0.1	4.9	13.3	270	220	280	250	130	430	135	430	34.0
3-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-4	1600	904	21	12.40	"	"	110	15.5	77	3.7	85	0.3	4.9	17.1	265	220	280	250	130	420	135	445	33.0
4-1	1640	1106	31	13.42	1100	10:1	-	22.6	80	-	-	0.1	9.3	10.31	280	235	285	270	135	500	140	520	34.5
4-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-3	*	*	*	*	"	"	100	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 171.3 / 174.7

0-200 ENGINE EMISSION DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIP	C.B	THC PPM-C	Co %	Nox PPM	CO_2 %	O_2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
1-1	905	10.0	10.47	10.3	18,340	10.53	12	7.25	2.3	511	5.92	.0011	77.34	897	.17	.141	1.64	.0003	.1022	1.18	.00022
1-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-4	905	16.2	16.69	16.6	16,280	10.51	10	7.46	7.8	.477	6.22	.0009	72.2	947	.14	.132	1.72	.00026	.095	1.24	.00018
2-1	906	11.5	11.78	12.0	5,230	9.21	35	9.21	2.3	.142	5.05	.0031	25.11	894	.56	.0392	1.39	.00087	.028	1.01	.0006
2-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-4	906	16.2	17.0	16.6	4,530	9.15	29	9.31	6.9	.116	4.74	.0025	20.57	840	.44	.0321	1.31	.0007	.023	.95	.0005
3-1	904	13.0	13.3	13.2	3,010	5.95	65	11.07	7.2	.0857	3.42	.0061	17.48	699	1.25	.0237	.95	.0017	.017	.68	.0012
3-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-4	904	16.2	17.1	16.8	3,450	5.60	56	11.2	6.0	.0886	2.91	.005	18.11	595	0.98	.0246	.81	.0013	.018	.58	.001
4-1	1106	10.0	10.31	10.5	7,340	11.08	20	8.07	1.5	.268	8.17	.0029	28.63	873	.25	.041	1.25	.0004	.018	.545	.00015
4-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4-3	*	14.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 171.2 / 174.7

0-200 ENGINE TEST DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
4-4	*	*	*	*	1100	10:1	110	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1630	1103	31	12.99	"	11.5:1	-	21.3	80	-	-	0.1	7.9	11.50	285	235	300	270	135	490	140	500	34.5
5-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-4	1630	1103	31	12.99	"	"	110	21.3	80	9.0	85	0.3	7.9	16.75	285	235	300	270	135	490	140	530	34.5
6-1	1625	1100	31	12.32	"	13:1	-	20.1	78	-	-	0.1	6.55	13.18	285	235	300	270	130	505	140	505	35.0
6-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-4	1615	1100	31	12.32	"	"	110	20.1	78	5.0	85	0.3	6.55	16.60	295	235	300	270	130	490	140	515	35.0
7-1	1510	1704	73	20.91	1700	10:1	-	55.3	85	-	-	0.5	23.3	9.95	385	310	395	360	180	820	170	890	34.5
7-2	"	"	"	"	"	"	90	"	"	22.0	120	1.2	"	14.24	370	310	385	350	180	820	170	860	34.5
7-3	"	"	"	"	"	"	100	"	"	25.0	130	2.3	"	15.27	370	305	385	350	175	1360	175	1660	34.5
7-4	"	"	"	"	"	"	110	"	"	30.0	140	2.8	"	16.45	375	305	385	350	180	1490	175	1780	34.5
8-1	1500	1703	73	18.37	"	11.5:1	-	53.6	85	-	-	0.6	19.6	11.46	405	325	420	385	170	815	175	890	35.0
8-2	"	"	"	"	"	"	90	"	"	9.0	110	0.9	"	13.56	395	315	420	380	175	840	175	970	34.5

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 171.3 / 174.7

O-200 ENGINE EMISSION DATA

DATE : Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN No	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
4-4	*	16.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1103	11.5	11.50	11.7	3,780	10.02	49	8.96	2.15	.146	7.92	.0063	18.46	990	.79	.0224	1.20	.001	.0097	.521	.0004
5-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-4	1103	16.2	16.75	16.1	3,610	9.68	47	9.14	6.8	.135	7.30	.006	17.08	924	.73	.0207	1.12	.0009	.009	.49	.0004
6-1	1100	13.0	13.18	13.2	2,810	6.32	78	10.9	2.35	.103	4.68	.0095	15.74	714	1.46	.016	.72	.0015	.0069	.312	.0006
6-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.
6-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.
6-4	1100	16.2	16.60	16.4	2,630	6.31	78	10.92	6.1	.096	4.54	.0092	14.6	694	1.41	.015	.70	.0014	.0064	.303	.0006
7-1	1704	10.0	9.95	9.8	6,090	13.61	14	6.93	0.9	.54	24.36	.004	23.16	1046	.17	.023	1.03	.00017	.0045	.203	.0003
7-2	"	13.2	14.34	14.1	5,790	13.15	16	7.19	6.5	.56	25.65	.005	23.96	1101	.22	.0236	1.08	.00024	.0047	.214	.00004
7-3	"	14.7	15.27	14.8	440	2.02	29	12.84	1.05	.072	9.65	.0156	3.09	416	.67	.003	.41	.00065	.00059	.08	.00012
7-4	"	16.2	16.45	15.8	200	1.42	33	13.61	1.9	.034	4.88	.0186	1.47	210	.80	.0014	.21	.0008	.00028	.041	.00015
8-1	1703	11.5	11.46	10.8	3,430	10.91	66	8.54	0.85	.34	21.81	.0216	17.31	1113	1.1	.143	.92	.0009	.00283	.181	.00017
8-2	"	13.2	13.56	13.7	1,440	2.20	49	13.1	0.5	.178	5.50	.02	9.06	231	1.01	.0075	.23	.00085	.00148	.046	.00016

TEST CONDITION: SECONDARY AIR.
IGNITION TIMING: 23° BTDC
ENGINE HRS: 171.3 / 174.7

0-200 ENGINE TEST DATA

DATE : Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG.

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
8-3	1500	1703°	73	18.39	1700	11.5:1	100	53.6	85	15.0	110	1.2	19.6	15.19	405	330	420	380	175	1220	175	1440	34.5
8-4	"	"	"	"	"	"	110	"	"	20.0	125	1.6	"	16.32	405	330	420	380	175	1315	175	1550	34.5
9-1	1445	1703	"	18.34	"	13:1	–	52.1	80	–	–	0.5	17.2	12.92	415	325	430	385	130	840	165	920	37.0
9-2	"	"	"	"	"	"	90	"	"	2.50	85	0.6	"	13.20	415	335	430	390	145	845	165	925	36.0
9-3	"	"	"	"	"	"	100	"	"	8.0	90	0.8	"	15.01	420	325	435	400	160	1070	170	1280	35.5
9-4	"	"	"	"	"	"	110	"	"	12.5	105	1.2	"	16.10	420	340	440	405	160	1190	170	1400	35.0
10-1	1710	1950	96	23.35	1950	13:1	–	80.6	95	–	–	0.9	32.9	9.91	425	350	440	425	200	910	190	990	33.0
10-2	"	"	"	"	"	"	90	"	"	21.0	145	2.9	"	13.44	420	340	430	420	200	1345	190	1620	33.0
10-3	"	"	"	"	"	"	100	"	"	33.0	160	3.8	"	15.22	420	350	435	420	205	1495	190	1790	33.0
10-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1705	1950	96	21.26	"	11.5:1	–	71.0	95	–	–	0.7	24.7	11.63	445	345	470	435	190	920	190	1010	34.5
11-2	"	"	"	"	"	"	90	"	"	10.0	120	1.2	"	13.44	445	345	465	435	190	1100	190	1300	34.0
11-3	"	"	"	"	"	"	100	"	"	19.0	125	1.6	"	15.17	445	345	465	435	195	1295	190	1540	33.5
11-4	"	"	"	"	"	"	110	"	"	22.0	145	2.6	"	16.13	450	350	470	450	200	1400	190	1620	33.5
12-1	1650	1945	"	21.24	"	13:1	–	70.0	98	–	–	0.7	22.6	12.85	460	350	470	460	160	945	185	1030	37.0

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 22° BTDC
ENGINE RPC: 176.3 / 174.7

0-200 ENGINE EMISSION DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 IN HG.

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B.	THC PPM-C	CO %	NOx PPM	CO_2 %	O_2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
8-3	1703	14.7	15.19	14.6	260	1.74	47	13.45	0.9	.036	4.82	.0214	1.83	246	1.09	.0015	.204	.0009	.00029	.04	.00017
8-4	"	16.2	16.32	15.3	25	.61	52	14.04	1.6	.0033	1.68	.0237	.17	86	1.21	.00014	.071	.001	.00002	.014	.00019
9-1	1703	13.0	12.92	12.3	2,410	6.22	213	10.99	0.7	.232	12.07	.068	13.47	702	3.95	.0098	.51	.0029	.0019	.101	.00056
9-2	"	13.2	13.20	12.7	1,985	5.99	210	11.15	1.2	.198	12.07	.069	11.52	702	4.06	.0084	.51	.003	.00164	.101	.0006
9-3	"	14.7	15.01	14.0	230	2.55	183	13.05	0.9	.027	5.97	.07	1.55	345	4.02	.0011	.252	.003	.00022	.050	.00058
9-4	"	16.2	16.10	15.1	33	.74	169	13.97	1.4	.004	1.90	.072	.24	111	4.17	.0002	.080	.003	.00003	.016	.00059
10-1	1950	10.0	9.91	9.8	5,460	13.08	27	7.26	0.6	.683	33.1	.0113	20.8	1005	.34	.0192	.93	.0003	.068	3.31	.0011
10-2	"	13.2	13.49	12.7	505	5.04	25	11.77	0.35	.103	20.8	.0167	3.14	634	.51	.0029	.585	.0005	.01	2.08	.0017
10-3	"	14.7	15.22	14.6	65	1.72	45	13.48	1.3	.014	7.7	.0327	.43	234	.97	.0004	.22	.0009	.0014	.77	.0033
10-4	–	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1950	11.5	11.63	11.2	2440	9.33	176	9.43	0.65	.313	24.18	.054	12.65	979	2.17	.0088	.68	.0015	.0313	2.42	.005
11-2	"	13.2	13.44	12.6	430	5.68	91	11.46	0.6	.066	17.46	.046	2.67	707	1.85	.00185	.49	.0013	.0066	1.77	.005
11-3	"	14.7	15.17	14.5	160	2.80	58	12.93	0.85	.028	9.77	.033	1.11	396	1.35	.0008	.274	.0009	.0028	.98	.0033
11-4	"	16.2	16.13	16.3	10	.32	96	14.18	2.7	.001	1.10	.055	.04	45	2.21	.00003	.031	.0015	.0001	.110	.0055
12-1	1925	13.0	12.85	12.1	2,010	7.69	305	10.79	0.65	.27	20.26	.132	11.93	897	5.34	.0076	.57	.0037	.027	2.03	.013

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 171.3 / 174.7

0-200 ENGINE TEST DATA

DATE: Oct 7, 1972
REL. HUMIDITY: 60 % / 60 %
BARO. PRESSURE: 29.20 / 29.20 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
12-2	1650	1945	96	21.24	1950	13:1	90	70.0	88	4.0	95	0.9	22.6	13.65	460	365	480	460	165	1030	185	1140	36.0
12-3	"	"	"	"	"	"	100	"	"	11.0	105	1.5	"	15.04	450	360	480	450	175	1180	190	1370	35.5
12-4	"	"	"	"	"	"	110	"	"	18.0	120	1.8	"	16.10	450	365	480	450	180	1280	190	1500	35.0
13-1	1740	2750	135	28.11	2750	10:1	–	146.0	100	–	–	2.0	55.9	10.19	580	480	550	–	260	1040	230	1180	30.5
13-2	"	"	125	"	"	"	90	"	"	36.0	200	3.8	"	13.23	580	480	530	–	255	1540	230	1840	30.5
13-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	1730	2750	145	28.11	"	11.5:1	–	142.0	105	–	–	1.9	49.3	11.24	585	490	595	–	260	1085	235	1220	30.5
14-2	"	"	140	"	"	"	90	"	"	22.0	175	3.6	"	13.46	595	490	595	–	260	1290	235	1510	30.5
14-3	"	"	130	"	"	"	100	"	"	40.0	210	3.8	"	15.13	585	490	595	–	260	1500	235	1810	30.5
14-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1720	2750	148	28.11	"	13:1	–	141.4	100	–	–	2.0	43.5	12.92	560	470	595	–	215	1125	220	1280	36.0
15-2	"	"	145	"	"	"	90	"	"	6.0	135	2.3	"	13.57	570	480	620	–	220	1190	220	1360	34.5
15-3	"	"	140	"	"	"	100	"	"	16.0	160	3.2	"	14.42	585	495	645	–	230	1330	230	1540	32.0
15-4	"	"	135	"	"	"	110	"	"	35.0	210	3.8	"	16.63	585	495	645	–	250	1400	235	1660	31.0

TEST CONDITION : SECONDARY AIR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 171.3 / 174.7

0-200 ENGINE EMISSION DATA

DATE : Oct 7, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.20 / 29.20 in HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR.	C.B	THC PPM-C	Co %	NOx PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
12-2	1945	12.2	13.65	12.9	850	5.50	321	11.51	0.9	.115	14.98	.144	5.11	663	6.25	.0033	.421	.004	.011	1.5	.014
12-3	"	14.7	15.04	13.9	105	2.13	222	13.27	0.4	.016	6.74	.115	.70	298	5.10	.00045	.189	.0023	.002	.674	.011
12-4	"	16.2	16.10	15.1	50	1.08	178	13.80	1.55	.008	3.74	.101	.36	166	4.49	.00023	.105	.0029	.308	.374	.010
13-1	2750	10.0	10.19	9.9	4,950	12.43	68	7.63	0.4	1.138	57.72	.052	20.36	1033	.93	.0161	.82	.0007	.0057/.095	.289/4.81	.0003/.0043
13-2	"	13.2	13.23	13.3	700	3.69	78	12.43	0.7	.268	28.61	.099	4.80	512	1.77	.0041	.437	.0015	.0013/.022	.143/2.38	.0005/.0082
13-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-4	-	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-1	2750	11.5	11.24	10.8	2,710	10.10	125	9.02	0.4	.634	47.75	.079	12.86	969	2.02	.0084	.63	.0013	.0032/.053	.239/4.0	.0005/.0082
14-2	"	13.2	13.46	12.5	655	6.2	87	11.18	0.3	.191	26.46	.084	3.27	740	1.71	.0026	.50	.0012	.001/.016	.182/3.04	.0004/.007
14-3	"	14.7	15.13	14.4	37	1.32	136	13.67	1.4	.0124	9.05	.153	.25	184	3.10	.0002	.133	.0023	.00006/.001	.045/.75	.0008/.013
14-4	-	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-1	2750	13.0	12.92	12.3	1,770	6.41	414	11.11	.45	.438	30.53	.634	10.05	702	7.80	.0057	.39	.0044	.0022/.037	.153/2.54	.0002/.0029
15-2	"	13.2	13.57	12.6	415	5.39	398	11.60	.45	.107	28.15	.342	2.45	647	7.85	.0014	.371	.0045	.0005/.009	.141/2.35	.0017/.029
15-3	"	14.7	14.62	14.0	160	2.46	386	13.10	.85	.048	14.80	.381	1.09	340	8.75	.0007	.202	.0052	.00024/.004	.074/1.23	.0019/.032
15-4	"	16.2	16.63	16.4	10	.21	559	14.24	2.8	.002	1.22	.569	.05	30	13.07	.00003	.019	.0080	.00001/.0002	.0066/.11	.003/.047

TEST CONDITION: Secondary Air
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

0-200 ENGINE TEST DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERATURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CCSE	COWLING	EXH. GAS	
1-1	910	904	21	13.20	900	10:1	–	17.9	82	–	–	0.1	7.7	9.95	260	215	270	245	135	425	130	435	34.0
1-2	–	–	–	–	"	"	90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1-4	910	904	21	13.20	"	"	110	17.9	82	10.0	80	1.2	7.7	16.44	260	215	275	240	135	425	130	445	34.0
2-1	930	904	"	12.38	"	11.5:1	–	14.8	84	–	–	0.1	5.35	11.77	270	225	280	250	135	440	130	460	34.0
2-2	–	–	–	–	"	"	90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2-4	930	904	21	12.38	"	"	0	14.8	84	5.5	80	0.7	5.3	16.55	270	225	280	250	135	440	130	450	34.0
3-1	945	903	"	12.23	"	13:1	–	14.5	82	–	–	0.1	4.5	13.09	285	235	275	255	135	455	135	460	34.0
3-2	–	–	–	–	"	"	90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3-4	945	903	21	12.23	"	"	110	14.5	82	3.0	80	0.3	4.5	16.33	280	235	275	260	135	435	135	460	34.0
4-1	1145	1102	31	14.45	1100	10:1	–	24.1	78	–	–	0.1	10.3	10.15	270	225	280	270	135	550	130	575	34.0
4-2	*	*	*	*	"	"	90	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-3	*	*	*	*	"	"	100	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 18° BTDC
ENGINE NO: 174.7 / 177.2

O-200 ENGINE EMISSION DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 27.50 IN HG

RUN NO	R.P.M	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
1-1	904	10.0	9.95	10.4	17,130	11.42	13	7.07	2.5	0.551	7.41	.0013	71.5	963	.17	.1522	2.05	.0004	.11	1.48	.0003
1-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-4	904	16.2	16.44	16.5	16,440	10.60	12	7.55	7.2	.475	6.19	.0012	61.7	804	.15	.1315	1.712	.0003	.095	1.24	.0002
2-1	904	11.5	11.77	12.1	4,780	9.27	41	9.38	2.5	.125	4.38	.0035	23.5	921	.66	.0345	1.25	.001	.025	.98	.0007
2-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-4	904	16.2	16.55	16.0	4,290	9.83	32	9.16	6.5	.101	4.66	.0025	19.06	320	.47	.028	1.29	.0007	.02	.932	.0005
3-1	903	13.0	13.09	13.1	2,910	5.85	72	11.38	2.2	.077	3.12	.0062	17.11	694	1.40	.0213	.86	.0017	.015	.624	.0013
3-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-4	903	16.2	16.33	16.4	3,470	5.30	63	11.69	5.2	.076	2.76	.0046	16.96	523	1.03	.0211	.65	.0013	.015	.47	.0009
4-1	1102	10.0	10.15	10.4	7,980	11.3	15.01	8.04	1.2	.15	9.01	.002	30.56	875	.19	.0414	1.33	.0003	.021	.601	.0001
4-2	*	13.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-3	*	14.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

0-200 ENGINE TEST DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR COVE	COWLING	EXH. GAS	
4-4	*	*	*	*	1100	10:1	110	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1135	1100	31	12.28	"	11.5:1	-	20.6	80	-	-	0.1	7.5	11.73	280	225	295	270	140	500	135	510	32.0
5-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-4	*	*	*	*	"	"	110	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6-1	1125	1105	31	12.56	"	13:1	-	20.0	82	-	-	0.1	6.55	13.07	305	240	315	285	165	530	140	560	32.5
6-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-4	1125	1105	31	12.56	"	"	110	20.0	82	5.1	85	0.4	6.55	16.54	295	235	310	280	155	520	140	565	33.0
7-1	1115	1703	73	19.76	1700	10:1	-	54.9	85	-	-	0.5	23.15	10.04	380	315	390	360	170	250	165	930	34.0
7-2	"	"	"	"	"	"	90	"	"	18.0	115	1.2	"	13.66	380	300	380	350	175	1250	165	1480	34.0
7-3	"	"	"	"	"	"	100	"	"	24.0	125	2.3	"	15.19	380	310	330	350	175	1410	165	1700	34.0
7-4	"	"	"	"	"	"	110	"	"	28.0	135	3.2	"	16.05	380	320	380	350	170	1500	170	1760	34.0
8-1	1105	1705	"	19.33	"	11.5:1	-	51.7	85	-	-	0.5	19.2	11.40	405	330	470	380	175	850	170	940	34.5
8-2	"	"	"	"	"	"	90	"	"	8.0	95	0.5	"	13.25	390	330	410	270	175	1010	170	1160	34.5

TEST CONDITION: Secondary Air
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

0-200 ENGINE EMISSION DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 in HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		IOM.	DIR.	C.E.	THC PPM	Co %	NOx PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
4-4	1102	16.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1100	11.5	11.73	11.6	3,960	9.47	44.2	9.36	1.55	.145	6.97	.0053	19.27	930	.71	.0223	1.07	.0008	.01	.465	.0004
5-2	"	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
5-3	"	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-4	"	16.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
6-1	1105	13.0	13.07	12.6	2,710	6.17	74	10.98	1.80	.079	4.72	.009	14.92	721	1.25	.015	.72	.0014	.0065	.315	.0006
6-2	"	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
6-3	"	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-4		16.2	16.22	15.7	2,240	5.5	74	11.52	1.6	.08	3.96	.009	12.20	605	1.33	.013	.61	.0013	.0053	.264	.006
7-1	1703	10.0	10.04	9.9	6,960	12.2	18	7.7	.40	.624	27.07	.0054	26.05	954	.23	.0264	.93	.0002	.0052	.184	.00004
7-2	"	13.2	13.66	12.6	635	5.59	20	11.63	.45	.091	16.21	.0094	2.92	700	.40	.0038	.685	.0004	.0008	.135	.00007
7-3	"	14.7	15.19	13.9	175	2.26	35	13.34	.50	.028	7.16	.0181	1.20	310	.78	.0012	.30	.0008	.00023	.06	.00015
7-4	"	16.2	16.05	15.4	20	.79	39	14.10	1.80	.003	2.56	.0209	.13	111	.90	.0001	.11	.0009	.00002	.021	.00017
8-1	1705	11.5	11.40	10.9	2,360	10.15	63	9.13	.50	.277	19.26	.020	14.44	1024	1.05	.0012	.84	.00085	.0023	.165	.00016
8-2	"	13.2	12.75	13.0	750	5.59	77	11.50	[illegible]	.102	13.17	.0274	[illegible]	635	1.43	.00432	.514	.0012	.3084	.102	.00022

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

0-200 ENGINE TEST DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60 % / 60 %
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
8-3	1105	1705	73	19.33	1700	11.5:1	100	51.7	55	12.0	105	0.9	19.2	14.25	390	330	410	370	175	1190	170	1400	34.5
8-4	"	"	"	"	"	"	110	"	"	20.0	115	1.8	"	16.43	390	330	410	370	175	1300	170	1490	34.5
9-1	1055	1702	"	19.02	"	13:1	-	50.0	82	-	-	0.5	16.3	13.13	420	335	430	390	160	890	170	930	35.0
9-2	"	"	"	"	"	"	90	"	"	0.6	82	0.5	"	13.46	420	340	430	390	165	920	170	1020	34.5
9-3	"	"	"	"	"	"	100	"	"	5.0	90	0.8	"	14.7	420	340	430	390	170	1100	175	1305	34.5
9-4	"	"	"	"	"	"	110	"	"	10.0	105	1.1	"	15.6	420	340	430	390	170	1200	175	1340	34.5
10-1	1230	1950	96	23.23	1950	10:1	-	76.0	57	-	-	0.8	32.1	9.96	420	340	430	420	190	930	175	1020	34.0
10-2	"	"	"	"	"	"	90	"	"	20.0	145	2.0	"	12.98	400	345	420	410	190	1380	175	1660	34.0
10-3	"	"	"	"	"	"	100	"	"	30.0	160	2.9	"	14.73	400	360	420	410	190	1495	175	1790	34.0
10-4	-	-	-	-	"	"	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11-1	1220	1950	96	21.85	"	11.5:1	-	70.4	87	-	-	0.7	26.0	11.39	425	335	445	420	180	945	180	1040	35.0
11-2	"	"	"	"	"	"	90	"	"	12.0	120	1.2	"	13.52	425	335	445	420	185	1165	180	1380	34.5
11-3	"	"	"	"	"	"	100	"	"	20.0	135	2.0	"	14.59	425	360	445	420	185	1300	180	1540	34.5
11-4	"	"	"	"	"	"	110	"	"	28.0	145	3.2	"	15.22	430	360	455	420	190	1325	180	1615	34.5
12-1	1210	1950	"	21.97	"	13:1	-	71.3	83	-	-	0.7	23.7	12.83	435	345	465	440	150	995	130	1100	37.0

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

O-200 ENGINE EMISSION DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60 % / 60 %
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO₂ %	O₂ %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
8-3	1705	14.7	14.25	13.2	125	2.24	61	13.36	.35	.015	5.63	.025	.79	293	1.30	.00064	.237	.0011	.0012	.47	.0002
8-4	"	16.2	16.43	15.7	7	.21	71	14.38	1.85	.001	.55	.0315	.04	29	1.64	.00003	.023	.0013	–	.0046	.0003
9-1	1702	13.0	13.13	12.8	1,780	4.22	336	11.90	.55	.17	9.28	.106	10.4	570	6.51	.0071	.39	.0045	.0014	.077	.0009
9-2	"	13.2	13.66	13.0	1150	4.66	348	12.05	0.8	.115	9.38	.115	7.06	576	7.07	.0049	.40	.005	.001	.078	.001
9-3	"	14.7	14.70	14.1	88	1.76	196	13.60	.55	.010	3.98	.073	.60	244	4.47	.0004	.17	.003	.00008	.033	.0006
9-4	"	16.2	15.60	15.0	12	.41	183	14.29	.95	.0015	.98	.073	.09	60	4.48	.00006	.04	.003	.00012	.0082	.0006
10-1	1950	10.0	9.96	9.9	4,420	12.56	26	7.77	.30	.552	31.67	.0106	17.18	987	.33	.0155	.89	.0003	.055	3.17	.0011
10-2	"	13.2	12.98	12.9	310	4.61	22	12.16	.45	.059	17.72	.0136	1.83	552	.42	.0017	.50	.0004	.0059	1.77	.0014
10-3	"	14.7	14.73	14.0	135	2.37	43	13.29	.75	.028	10.09	.0297	.88	314	.92	.0008	.28	.0008	.0028	1.01	.003
10-4	"	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1950	11.5	11.39	10.9	2,515	9.94	72	9.27	.35	.327	26.04	.031	12.56	1002	1.19	.0092	.73	.0009	.033	2.60	.003
11-2	"	13.2	13.52	12.8	295	5.12	58	13.31	.48	.047	16.46	.031	1.81	633	1.18	.0013	.462	.0009	.0047	1.65	.003
11-3	"	14.7	14.89	13.9	110	2.33	59	14.31	.48	.020	8.70	.036	.77	335	1.38	.0006	.244	.0010	.002	.87	.0036
11-4	"	16.2	15.82	15.5	5	.31	94	14.33	1.55	.0006	1.24	.062	.02	49	2.37	.00002	.035	.0017	.00006	.124	.0062
12-1	1950	13.0	12.23	12.2	1765	6.07	233	11.27	.35	.238	16.53	.104	10.22	698	4.37	.0067	.46	.0029	.024	1.65	.010

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

0-200 ENGINE TEST DATA

DATE : Oct 9, 1972
REL. HUMIDITY: 60 % / 60 %
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
12-2	1210	1950	96	21.97	1950	13:1	90	71.3	83	4.0	95	0.9	23.7	13.60	440	360	470	435	160	1100	180	1260	36.5
12-3	"	"	"	"	"	"	100	"	"	12.0	105	1.5	"	15.24	440	360	475	440	160	1240	185	1410	36.0
12-4	"	"	"	"	"	"	110	"	"	16.0	115	1.8	"	15.93	450	365	470	440	170	1300	185	1540	35.5
13-1	1255	2750	140	28.54	2750	10:1	–	141.3	105	–	–	2.0	56.7	9.82	550	455	520	455	250	1070	215	1220	31.0
13-2	"	"	125	"	"	"	90	"	"	46.0	220	3.8	"	13.90	550	455	500	430	250	1550	220	1820	31.5
13-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	1250	2750	145	28.54	"	11.5:1	–	139.6	105	–	–	2.0	48.3	11.39	570	480	595	535	235	1120	220	1260	32.0
14-2	"	"	140	"	"	"	90	"	"	22.0	175	3.6	"	13.66	565	470	580	520	245	1320	220	1565	31.5
14-3	"	"	135	"	"	"	100	"	"	32.0	210	3.8	"	14.60	570	470	570	515	245	1500	220	1750	31.0
14-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1240	2750	148	28.54	"	13:1	–	143.6	100	–	–	2.0	44.3	12.74	550	470	585	550	215	1160	225	1330	36.0
15-2	"	"	148	"	"	"	90	"	"	6.0	135	2.3	"	13.38	565	480	600	550	220	1210	225	1400	35.0
15-3	"	"	145	"	"	"	100	"	"	22.0	160	3.2	"	15.20	560	480	620	550	230	1325	225	1550	34.0
15-4	"	"	140	"	"	"	110	"	"	32.0	210	3.2	"	16.44	570	475	610	535	225	1490	225	1740	33.0

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

0-200 ENGINE EMISSION DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B.	THC PPM-C	Co %	Nox PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
12-2	1950	13.2	13.60	12.7	330	4.77	267	12.06	.25	.047	13.92	.127	2.00	587	5.28	.0013	.391	.0036	.0047	1.39	.013
12-3	"	14.7	15.24	14.0	40	1.48	274	13.74	.20	.006	4.79	.145	.26	202	6.13	.0002	.134	.0041	.0006	.48	.015
12-4	"	16.2	15.93	14.8	15	.59	192	14.17	.85	.0026	2.09	.112	.11	88	4.72	.00007	.059	.0031	.0003	.21	.011
13-1	2750	10.0	9.82	9.9	5,520	11.78	66	8.05	.1	1.22	52.62	.048	21.5	928	.85	.0167	.72	.0007	.0061 .102	.263 4.39	.00024 .006
13-2	"	13.2	13.90	12.8	1,515	4.35	70	12.16	.17	.536	31.11	.082	9.45	549	1.45	.0082	.475	.0013	.0027 .045	.156 2.59	.304 .007
13-3	"	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
13-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-1	2750	11.5	11.39	10.9	2310	9.54	135	9.49	.1	.562	46.9	.109	11.63	971	2.26	.0074	.62	.0014	.0028 .047	.234 3.91	.0006 .0091
14-2	"	13.2	13.66	12.4	140	5.59	86	11.63	.1	.041	33.2	.084	.26	688	1.73	.0006	.453	.0011	.0002 .0031	.166 2.77	[illegible] .007
14-3	"	14.7	14.60	13.9	85	2.18	156	13.39	.5	.03	15.2	.179	.62	315	3.70	.0004	.223	.0026	.00015 .0025	.076 1.27	.18 .05
14-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-1	2750	13.0	12.74	12.1	1575	6.26	260	11.20	.1	.396	31.74	.217	8.93	717	4.89	.005	.41	.0028	.002 .033	.159 2.65	.0011 .018
15-2	"	13.2	13.38	12.4	705	5.49	229	11.68	.1	.187	29.39	.201	4.21	663	4.57	.00241	.38	.0026	.0009 .016	.147 2.45	.001 .0167
15-3	"	14.7	15.20	13.6	222	3.35	226	12.80	.75	.066	20.26	.224	1.50	457	5.04	.0009	.27	.0030	.0003 .0055	.101 1.69	.001 .019
15-4	"	16.2	16.21	14.2	21	1.35	221	13.96	1.2	.0066	6.67	.229	.15	151	5.17	.00009	.09	.0031	.0002 .0005	.032 .56	.0011 .019

TEST CONDITION: SECONDARY AIR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 174.7 / 177.2

0-200 ENGINE EMISSION DATA

DATE: Oct 9, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM	DIR	C.B	THC PPM-C	Co %	Nox PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
12-2	1950	13.2	13.60	12.7	330	4.79	267	12.06	.25	.047	13.92	.127	2.00	587	5.38	.0013	.391	.0036	.0047	1.39	.013
12-3	"	14.7	15.24	14.0	40	1.48	274	13.74	.20	.006	4.79	.145	.26	202	6.13	.0002	.134	.0041	.0006	.48	.015
12-4	"	16.2	15.93	14.8	15	.59	192	14.17	.85	.0026	2.09	.112	.11	88	4.72	.00007	.059	.0031	.0003	.21	.011
13-1	2750	10.0	9.82	9.9	5,520	11.78	66	8.05	.1	1.22	52.62	.048	21.5	928	.85	.0167	.72	.0007	.0061 .102	.263 4.39	.00024 .006
13-2	"	13.2	13.90	12.9	1,515	4.35	70	12.16	.17	.536	31.11	.082	9.45	549	1.45	.0082	.475	.0013	.0027 .045	.156 2.59	.304 .007
13-3	"	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
13-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-1	2750	11.5	11.39	10.9	2310	9.54	135	9.49	.1	.562	46.9	.109	11.63	971	2.26	.0074	.62	.0014	.0028 .047	.234 3.91	.0006 .0091
14-2	"	13.2	13.66	12.4	140	5.59	86	11.48	.1	.041	33.2	.084	.26	688	1.73	.0006	.453	.0011	.0002 .0071	.166 2.77	.0004 .007
14-3	"	14.7	14.60	13.9	95	2.18	156	13.39	.5	.03	15.2	.179	.62	315	3.70	.0004	.203	.0026	.00015 .0025	.076 1.27	.18 .015
14-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-1	2750	13.0	12.74	12.1	1575	6.26	260	11.20	.1	.396	31.74	.217	8.93	717	4.89	.005	.41	.0028	.002 .033	.159 2.65	.0011 .018
15-2	"	13.2	13.38	12.4	705	5.49	229	11.68	.1	.187	29.39	.201	4.21	663	4.57	.00241	.38	.0026	.0009 .016	.147 2.45	.001 .0167
15-3	"	14.7	15.20	13.6	222	3.35	226	12.80	.75	.066	20.26	.224	1.50	457	5.04	.0009	.27	.0030	.0003 .0055	.101 1.69	.0017 .019
15-4	"	16.2	16.21	14.2	21	1.05	221	13.96	1.2	.0066	6.67	.229	.15	151	5.17	.00007	.09	.0031	.00002 .0005	.032 .56	.0011 .019

APPENDIX B4

THERMAL REACTOR EVALUATION

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 150.4 / 156.2

0-200 ENGINE TEST DATA

DATE: Sept 29, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	TIME	RPM	TORQUE FT/LBS	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
1-1	1155	903°	21	13.72	900	10:1	0	18.4	76	—	—	0.25	7.9	[illegible]	240	200	245	210	105	805 755	140	435	32.0
1-2	"	"	"	"	"	"	90	"	"	6.2	78	0.60	"	13.65	245	200	250	215	110	780 720	145	470	"
1-3	"	"	"	"	"	"	100	"	"	8.3	78	0.80	"	"	240	200	250	215	110	730 670	145	480	"
1-4	"	"	"	"	"	"	110	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
2-1	1115	900	"	12.28	"	11.5:1	0	16.3	82	—	—	0.25	5.85	11.76	240	200	260	235	130	760 735	150	390	32.0
2-2	"	"	"	"	"	"	90	"	"	2.25	86	0.8	"	13.52	240	200	250	235	130	745 730	150	405	"
2-3	"	"	"	"	"	"	100	"	"	4.3	86	1.25	"	15.25	240	200	245	230	130	720 700	150	415	"
2-4	"	"	"	"	"	"	110	"	"	6.3	86	1.45	"	16.90	240	200	245	230	130	720 695	150	450	"
3-1	1140	901	"	11.57	"	13:1	0	15.7	82	—	—	0.25	4.95	13.29	240	200	260	235	130	740 750	150	370	32.0
3-2	"	"	"	"	"	"	90	"	"	0.5	84	.25	"	13.83	240	210	265	240	130	770 760	150	390	"
3-3	"	"	"	"	"	"	100	"	"	2.1	84	.25	"	15.26	240	210	265	240	130	760 740	150	400	"
3-4	"	"	"	"	"	"	110	"	"	3.9	84	0.5	"	16.92	240	200	265	240	130	745 720	155	410	"
4-1	1530	1104	31	13.94	1100	10:1	0	23.4	80	—	—	0.30	9.8	10.15	260	225	280	255	130	870 830	160	520	32.0
4-2	"	"	"	"	"	"	90	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"
4-3	"	"	"	"	"	"	100	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"	"

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 150.4 / 156.2

O-200 ENGINE EMISSION DATA

DATE : SEPT 29, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO_2 %	O_2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
1-1	903	10.0	10.03	10.1	18,270	11.07	6	6.92	1.5	.586	7.12	.0006	74.2	902	.57	.162	1.97	.0002	.117	1.47	.0001
1-2	"	13.2	13.65	13.1	13,500	10.38	9	6.75	1.8	.461	8.54	.0010	58.4	1020	.13	.128	2.36	.0003	.097	1.71	.0002
1-3	"	14.7	14.8	14.6	13,300	10.21	8	6.80	4.9	.46	8.32	.0009	57.8	1030	.12	.125	2.21	.0003	.095	1.69	.0002
1-4	"	16.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2-1	900	11.5	11.76	10.9	7,480	10.19	20	8.85	1.35	.215	5.91	.0019	36.7	1010	.32	.060	1.64	.0005	.043	1.18	.0004
2-2	"	13.2	13.52	12.9	7,460	10.51	18	8.22	3.40	.216	6.05	.0017	36.9	1035	.29	.060	1.68	.0005	.043	1.21	.00035
2-3	"	14.7	15.25	14.7	8,120	10.70	16	9.63	4.5	.222	5.91	.0015	38.0	894	.25	.062	1.64	.0004	.044	1.18	.0003
2-4	"	16.2	16.90	16.3	7,860	9.75	17	8.63	7.5	.209	5.23	.0015	35.7	791	.25	.058	1.45	.0004	.042	1.05	.0003
3-1	901	13.0	13.29	12.4	4,540	6.88	45	10.4	1.55	.128	3.91	.0042	25.8	700	.85	.036	1.09	.0012	.026	.78	.00085
3-2	"	13.2	13.23	13.6	4,590	6.80	46	10.83	3.0	.124	3.33	.0043	25.1	683	.88	.035	.94	.0012	.025	.67	.00085
3-3	"	14.7	15.26	14.7	4,200	6.65	45	10.59	4.4	.113	3.54	.0040	22.8	715	.80	.032	.98	.0011	.023	.71	.0008
3-4	"	16.2	16.9	16.6	3,820	6.65	46	10.50	6.5	.101	3.56	.0036	20.5	719	.74	.032	.98	.0010	.023	.71	.0007
4-1	1104	10.0	10.15	10.1	9,250	11.84	12	7.45	1.0	.364	9.39	.0016	37.1	952	.16	.021	1.00	.0003	.024	.63	.0001
4-2	"	13.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-3		14.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 150.[illegible] / 156.2

O-200 ENGINE TEST DATA

DATE: Sept 29, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
4-4	*	*	*	*	1100	10:1	110	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1525	1103	31	12.36	"	11.5:1	0	19.8	80	–	–	0.3	7.3	11.53	270	235	295	265	130	875 885	165	490	32.0
5-2	"	"	"	"	"	"	90	"	"	2.6	80	0.3	"	13.09	270	230	225	260	130	845 860	160	500	"
5-3	"	"	"	"	"	"	100	"	"	5.7	80	0.5	"	15.33	265	230	285	260	130	940 960	160	590	"
5-4	"	"	"	"	"	"	110	"	"	8.3	80	0.8	"	16.59	265	230	285	260	130	1060 1080	160	655	"
6-1	1510	1102	"	12.68	"	13:1	0	20.7	77	–	–	0.3	6.75	13.17	280	240	300	270	135	905 910	160	470	33.0
6-2	"	"	"	"	"	"	90	"	"	0.6	78	0.3	"	13.56	290	245	300	270	135	910 910	165	500	"
6-3	"	"	"	"	"	"	100	"	"	2.8	78	0.3	"	15.02	285	245	310	280	135	905 915	165	520	"
6-4	"	"	"	"	"	"	110	"	"	5.1	78	0.4	"	16.59	285	245	310	280	135	890 925	165	545	"
7-1	1030	1706	73	20.22	1700	10:1	0	59.6	84	–	–	0.8	25.0	9.99	350	310	380	350	150	1045 1075	200	855	25.0
7-2	"	"	"	"	"	"	90	"	"	16.0	105	1.8	"	13.09	350	315	380	350	150	1000 1300	200	990	"
7-3	"	"	"	"	"	"	100	"	"	26	140	2.2	"	15.33	350	310	380	345	155	900 1500	205	1645	"
7-4	"	"	"	"	"	"	110	"	"	36.0	145	3.8	"	16.54	350	315	380	350	160	840 1560	210	1820	"
8-1	1045	1706	"	18.39	"	11.5:1	0	52.4	88	–	–	0.8	19.0	11.40	365	330	410	370	170	1100 1120 1105 1100	215	840	34
8-1-R	1330	1706		18.70				53.1	84	–	–	0.8	19.5	11.42	360	320	405	380	160		205	835	32
8-2	"	"	"	"	"	"	90	"	"	8.5	115	1.2	"	13.46	365	320	390	365	170	1160 1120	215	1030	"
8-2-R										8.8	105	1.25		13.52	365	320	410	365	160	1260 1200	210	1120	

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 150.4 / 156.2

0-200 ENGINE EMISSION DATA

DATE: SEPT 29, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR.	C.B.	THC PPM-C	CO %	NOx PPM	CO₂ %	O₂ %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
4-4	1104	16.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1103	11.5	11.53	11.5	3,960	9.30	61	9.25	1.25	.137	6.51	.007	12.9	892	.96	.0211	1.00	.0011	.009	.43	.0005
5-2	"	13.2	13.09	12.9	3,900	9.62	56	9.10	2.2	.128	6.40	.0061	17.6	876	.84	.0197	.98	.0007	.0086	.43	.0004
5-3	"	14.7	15.22	14.2	2,035	5.59	42	11.30	3.2	.083	4.58	.0064	11.3	627	.88	.0127	.70	.001	.0055	.31	.0004
5-4	"	16.2	16.57	15.7	1,060	3.49	48	12.41	4.7	.047	3.14	.007	6.5	429	.74	.0071	.48	[illegible]	.0031	.21	.0005
6-1	1102	13.0	13.17	13.1	2,595	[illegible]	116	11.39	1.5	.101	4.18	.0151	15.0	619	2.24	.0156	.64	.0023	.0067	.29	.001
6-2	"	13.2	13.56	13.5	2,650	5.42	116	11.32	2.2	.101	4.20	.0149	15.1	622	2.20	.0156	.65	.0023	.0068	.28	.001
6-3	"	14.7	15.02	14.7	2,250	4.99	126	11.57	3.5	.082	3.95	.0176	13.1	536	2.61	.0136	.61	.0027	.0059	.26	.0012
6-4	"	16.2	16.59	15.4	2,180	5.41	123	11.37	4.5	.085	4.24	.0161	13.7	625	2.28	.0171	.66	.0025	.0057	.29	.0011
7-1	1706	10.0	9.99	9.6	6,670	13.15	19	7.05	0.6	.626	25.3	.0050	25.5	1013	0.23	.0249	1.07	.0024	.0053	.21	.00005
7-2	"	13.2	13.09	12.9	4,915	10.59	24	8.51	2.6	.572	24.9	.0093	22.9	994	0.37	.0241	1.05	.0004	.0048	.21	.00008
7-3	"	14.7	15.33	14.3	295	3.13	38	12.7	1.8	.050	10.8	.0218	2.0	[illegible]	0.87	.0071	.46	.0009	.0004	.09	.0002
7-4	"	16.2	[illegible]	15.8	47	1.66	36	13.46	3.0	.008	5.9	.021	.33	235	.83	.0003	.25	.0009	.00006	.05	.00017
8-1	1706	11.5	11.40	11.2	4250	9.73	72	7.0	.95	.372	17.7	[illegible]	19.55	904	1.10	.0157	.72	.0009	.0031	.143	.00017
8-1-2	1706		[illegible]	[illegible]	3490	[illegible]	72	[illegible]	.65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.31	.0146	.90	.0011	.0029	.18	.00021
8-2	"	[illegible]	13.42	[illegible]	[illegible]	[illegible]	60	10.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	361	1.16	[illegible]	[illegible]	.0009	.0013	.136	.00012
8-2-1			[illegible]	[illegible]	470	4.69	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.55	.0024	[illegible]	[illegible]	.0005	[illegible]	[illegible]

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 150.4 / 156.2

0-200 ENGINE TEST DATA

DATE: Sept 29, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	TIME	RPM	TORQUE FT/LBS	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
8-3 8-3-R	1045 1330	1706 1706	73	18.29 18.70	1700	11.5:1	100	52.4 53.1	[illegible] 84	15.0 16.0	122 140	1.7 1.2	19.0 19.5	[illegible] 15.30	365 370	320 320	390 410	[illegible] 380	170 165	[illegible] 1415 [illegible]	215 215	[illegible] 1370	[illegible] 33.0
9-4 9-4-R	"	"	"	"	"	"	110	"	"	21.0 21.5	120 145	2.0 2.0	"	16.24 16.13	370 370	320 320	400 410	370 370	170 170	1500 1545 1460 [illegible]	220 220	1405 1080	"
9-1	1055	1703	"	18.25	"	13:1	0	51.0	88	–	–	0.75	16.5	13.00	385	340	420	385	175	1180 1170	220	890	33.0
9-2	"	"	"	"	"	"	90	"	"	3.0	115	0.9	"	13.22	390	345	425	390	175	1190 1170	220	880	"
9-3	"	"	"	"	"	"	100	"	"	7.6	125	1.2	"	15.12	390	345	430	390	175	1360 1345	230	1050	"
9-4	"	"	"	"	"	"	110	"	"	12.0	130	1.5	"	16.41	390	345	425	390	175	1410 1400	220	1250	"
10-1	1415	1954	96	24.30	1950	10:1	0	84.7	95	–	–	1.4	34.5	9.90	410	380	455	440	205	1140 1135	240	–	32.0
10-2	"	"	"	"	"	"	90	"	"	24.0	135	2.6	"	13.52	395	365	430	435	200	1510 1490	230	–	"
10-3	"	"	"	"	"	"	100	"	"	36.0	170	3.75	"	15.25	395	365	435	420	200	1530 1530	235	–	"
10-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1405	1950	96	21.97	"	11.5:1	0	79.1	94	–	–	1.3	28.3	11.21	415	380	480	450	200	1190 1175	240	1000	33.0
11-2	"	"	"	"	"	"	90	"	"	13.0	125	1.8	"	13.46	415	380	470	450	200	1420 1375	240.	1205	"
11-3	"	"	"	"	"	"	100	"	"	23.0	135	2.5	"	15.27	415	380	470	450	200	1480 1425	240	1430	"
11-4	"	"	"	"	"	"	110	"	"	30.0	175	3.8	"	16.46	420	380	470	450	200	1570 1490	240	1560	"
12-1	1350	1948	"	21.02	"	13:1	0	70.2	90	–	–	1.1	22.2	12.97	420	380	480	450	175	1260 1245	230	1000	34.0

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE [illegible]: 150-1 / 156-2

0-200 ENGINE EMISSION DATA

DATE: SEPT 29, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.10 / 29.10 in HG

RUN №	RPM	CALC. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC ppm	Co %	Nox ppm	CO₂ %	O₂ %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
8-3	1706	14.7	15.5	[illegible]	375	3.28	62	12.61	[illegible]	.047	8.66	.026	2.59	486	1.41	.0021	.365	.0011	.0004	.072	.00023
8-3-5	1706		15.34	13.9	375	3.25	57	12.30	.2	.051	10.51	[illegible]	2.62	542	1.32	.0021	.447	.0011	.0004	.082	[illegible]
8-4	"	16.2	15.24	[illegible]	75	.99	64	[illegible]	1.4	[illegible]	2.76	.0295	.34	146	1.55	.0004	.117	.0012	.00006	.025	[illegible]
8-4-5			16.5	14.4	60	1.1	59	12.72	1.25	[illegible]	[illegible]	[illegible]	.44	[illegible]	1.44	.00026	.134	.0012	[illegible]	.026	[illegible]
9-1	1703	13.0	13.0	12.9	2560	7.01	237	10.53	2.1	.248	13.69	.076	15.1	820	4.61	.0105	.58	.0032	.0021	.114	.00063
9-2	"	13.2	13.53	13.0	2,490	6.76	265	10.46	2.25	.256	14.03	.09	15.5	750	5.45	.0108	.52	.0038	.0021	.117	.00074
9-3	"	14.7	15.12	14.7	380	2.78	232	12.27	2.37	.043	6.3	.087	2.59	282	5.25	.0017	.27	.0037	.00043	.052	.00072
9-4	"	16.2	16.4	15.5	42	.84	202	12.07	2.50	.0056	2.0	.082	.34	122	4.91	.00025	.085	.0034	.00004	.017	.00067
10-1	1954	10.0	9.90	9.6	6,005	13.44	37	6.92	.45	.82	37.0	.017	23.7	1072	.49	.033	1.04	.0005	.032	2.7	.0017
10-2	"	13.2	13.52	13.2	716	3.27	46	12.58	.40	.156	14.0	.022	4.5	401	.93	.0041	.39	.0009	.015	1.4	.003
10-3	"	14.7	15.35	14.5	100	2.48	45	13.04	[illegible]	.022	11.2	.034	.64	325	.92	.0006	.34	.00015	.002	1.12	.003
10-4	"	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1970	11.5	11.21	11.5	3,650	8.83	115	9.52	.45	.462	22.6	.048	16.3	798	1.71	.013	.63	13.6	.046	2.26	.005
11-2	"	13.2	13.42	12.8	990	4.43	97	11.05	.50	.158	14.1	.051	5.6	510	1.81	.0044	.40	14.3	.015	1.44	.005
11-3	"	14.7	15.27	14.6	205	2.19	25	13.17	.65	.055	8.40	.051	1.9	297	1.91	.0015	.24	15.1	.005	.84	.005
11-4	"	16.2	16.46	16.1	17	.60	72	14.0	7.6	.012	4.23	.128	.54	100	5.74	.0003	.12	35.9	.001	.42	.012
12-1	[illegible]	13.0	12.92	[illegible]	2,220	6.41	44	[illegible]	.5	.221	[illegible]	.174	13.0	764	7.84	[illegible]	[illegible]	40.6	.029	1.7	[illegible]

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 150.4 / 156.2

0-200 ENGINE TEST DATA

DATE: Sept 29, 1972
REL. HUMIDITY: 60% / 10%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
12-2	1350	1935	96	21.02	1950	13:1	90	70.2	90	3.0	110	1.3	22.2	13.60	420	380	480	450	175	1370 1300	225	1070	34.0
12-3	"	"	"	"	"	"	100	"	"	9.5	125	1.7	"	15.00	420	380	480	450	190	1450 1405	235	1250	"
12-4	"	"	"	"	"	"	110	"	"	16.0	130	2.1	"	16.1	420	380	480	455	190	1480 1435	235	1405	"
13-1	1620	2745	129	27.95	2750	10:1	0	141.0	105	–	–	2.8	55.1	9.95	545	485	525	455	250	1225 1735	295	1130	30.0
13-2	"	"	"	"	"	"	90	"	"	40.0	200	3.8	"	13.60	550	480	525	430	245	1640 1570	290	1710	"
13-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	1610	2748	139	27.95	"	11.5:1	0	139.0	100	–	–	2.7	43.1	11.44	555	500	600	550	235	1290 1320	295	1195	31.0
14-2	"	"	135	"	"	"	90	"	"	22.0	145	3.8	"	13.79	555	500	590	530	240	1505 1490	290	1400	"
14-3	"	"	127	"	"	"	100	"	"	35.0	185	3.8	"	15.17	555	500	585	520	240	1600 1530	300	1655	"
14-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1600	2747	142	27.95	"	13:1	0	138.0	92	–	–	2.5	43.2	13.02	550	480	590	560	170	1220 1250	280	1220	32.0
15-2	"	"	142	"	"	"	90	"	"	4.0	90	3.8	"	13.50	560	495	620	565	190	1320 1490	290	1320	"
15-3	"	"	134	"	"	"	100	"	"	16.0	125	3.8	"	14.51	555	420	620	560	205	1470 1550	290	1470	"
15-4	"	"	132	"	"	"	110	"	"	34.0	130	3.8	"	15.42	555	500	620	570	220	[illegible] [illegible]	290	1600	"

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 150.4 / 156.2

O-200 ENGINE EMISSION DATA

DATE: Sept 29, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.10 / 29.10

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
12-2	1948	13.2	13.60	12.7	920	5.13	352	11.44	.5	.125	14.13	.162	5.64	412	7.30	.0035	.397	.0046	.013	1.41	.0162
12-3	"	14.7	15.00	13.0	230	2.96	246	12.70	.65	.035	9.15	.125	1.58	384	5.63	.001	.257	.0035	.004	.92	.0125
12-4	"	16.2	16.1	15.1	72	1.25	220	13.7	.90	.012	4.23	.128	.54	190	5.7	.00024	.119	.0036	.0012	.423	.013
13-1	2745	10.0	9.05	9.9	5,330	12.3	76	7.6	.30	1.17	54.3	.06	21.3	986	1.01	.017	.81	.0008	.0059 .097	.27 4.52	.0003 [illegible]
13-2	"	13.2	13.6	13.2	1,020	3.3	97	12.0	.65	.25	24.3	.111	6.4	477	2.02	.006	.23	.0018	.0018 .029	.122 2.19	.0006 [illegible]
13-3	"	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-1	2742	11.5	11.44	10.8	2,160	10.12	201	9.02	.25	.51	50.9	.166	11.2	1059	3.4	.0074	.7	.0023	.0027 .045	.255 4.24	.0008 .0124
14-2	"	13.2	13.79	12.3	960	6.42	158	10.97	.45	.29	34.0	.159	6.1	217	5.3	.0041	.56	.0023	.0015 .024	.197 3.27	.0058 .193
14-3	"	14.7	15.17	14.0	240	2.40	183	13.1	.75	.02	15.5	.178	1.6	322	4.1	.0012	.233	.003	.0004 [illegible]	.076 1.29	[illegible] .193
14-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-1	2747	13.0	13.02	12.1	1,890	6.34	490	10.7	.3	.49	33.2	.42	11.3	768	9.7	.0066	.45	.0057	.002 .011	.166 2.77	.0021 .035
15-2	"	13.2	13.50	12.4	694	4.7	391	11.9	.2	.19	25.7	.35	4.31	596	8.11	.0025	.344	.0047	.0009 .016	.129 2.14	.0018 .035
15-3	"	14.7	14.51	13.7	372	3.3	319	12.6	.18	.115	20.6	.33	2.4	433	6.8	.0016	.30	.0047	.0006 [illegible]	[illegible] 1.7	.0017 .027
15-4	[illegible]	16.2	15.42	[illegible]	124	1.4	[illegible]	13.6	.50	.04	[illegible]	.35	[illegible]	197	6.9	.0006	.11	[illegible]	[illegible] .003	[illegible]	.0017 [illegible]

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 22° BTDC
ENGINE HRS: 156.2 / 159.8

0-200 ENGINE TEST DATA

DATE: SEPT 30, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
1-1	-	-	-	-	900	10:1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-4	-	-	-	-	"	"	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-1	-	-	-	-	"	11.5:1	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-4	-	-	-	-	"	"	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-1	1120	903	21	12.40	"	13:1	0	15.3	75	-	-	-	4.95	13.22	240	210	265	240	145	805/825	150	420	32.0
3-2	-	-	-	-	"	"	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-3	-	-	-	-	"	"	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-4	1120	903	21	12.40	"	"	110	15.3	78	3.6	95	0.2	4.95	16.47	240	205	260	235	140	825/860	150.	435	32.0
4-1	1210	1099	31	13.53	1100	10:1	0	22.5	76	-	-	-	9.9	10.[illegible]	260	220	275	245	140	825/825	155	560	34.0
4-2	*	*	*	*	"	"	90	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-3	*	*	*	*	"	"	100	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 22° BTDC
ENGINE HRS: 156.2 / 159.8

0-200 ENGINE EMISSION DATA

DATE: SEPT 30, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN No	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
1-1	-	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-4	-	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-1	-	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-4	-	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-1	9.3	13.0	13.22	12.3	3,180	7.41	49	10.59	2.45	.091	4.13	.0045	18.1	844	.92	.024	1.14	.0013	.018	.826	.0009
3-2	-	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-4	903	16.2	16.47	15.8	3,370	6.72	35	10.60	5.30	.092	3.69	.0032	18.7	753	.64	.025	1.02	.0009	.018	.738	.00065
4-1	1099	10.0	10.23	10.4	7,950	12.62	14	7.95	1.35	.273	9.33	.0017	29.4	942	.17	.045	1.44	.00026	.019	.622	.00011
4-2	*	13.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-3	*	14.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 22° BTDC
ENGINE HRS: 156.2 / [illegible]

0-200 ENGINE TEST DATA

DATE : SEPT 20, 1972
REL. HUMIDITY: 50 % / 50 %
BARO. PRESSURE: 29.16 / 29.16 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
4-4	*	*	*	*	1100	10:1	110	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1150	1100	31	12.56	"	11.5:1	0	21.0	76	–	–	–	7.2	11.60	265	225	285	255	140	905 / 960	160	535	33.0
5-2	"	"	"	"	"	"	90	"	"	2.5	80	.2	"	12.98	260	220	280	250	140	875 / 910	155	525	"
5-3	"	"	"	"	"	"	100	"	"	5.1	"	.5	"	14.60	260	220	280	250	140	845 / 890	150	740	"
5-4	"	"	"	"	"	"	110	"	"	7.9	"	.8	"	16.33	260	220	280	250	140	1070 / 1085	155	900	"
6-1	1135	1098	"	12.44	"	13:1	0	20.8	75	–	–	–	6.8	13.22	270	230	285	260	140	885 / 915	155	480	33.0
6-2	"	"	"	"	"	"	90	"	"	.6	85	.1	"	13.61	270	230	290	260	145	940 / 960	155	560	"
6-3	"	"	"	"	"	"	100	"	"	2.0	84	.2	"	14.60	270	230	290	260	145	905 / 960	160	560	"
6-4	"	"	"	"	"	"	110	"	"	5.0	84	.5	"	16.60	270	230	285	260	145	1120 / 1175	155	620	"
7-1	1105	1706	73	20.01	1700	10:1	0	57.8	82	–	–	.7	24.4	10.00	360	310	390	370	175	1120 / 1115	205	925	34.0
7-2	"	"	"	"	"	"	90	"	"	22.0	125	2.3	"	13.49	360	310	390	360	175	1540 / 1510	205	1450	"
7-3	"	"	"	"	"	"	100	"	"	25.0	145	3.8	"	15.60	360	310	390	365	175	1600 / 1580	205	1620	"
7-4	"	"	"	"	"	"	110	"	"	30.0	150	3.8	"	16.70	350	310	385	360	175	1650 / 1620	210	1650	"
8-1	1050	1702	"	18.98	"	11.5:1	0	52.1	80	–	–	.55	19.2	11.53	370	330	410	350	170	1145 / 1140	205	870	33.0
8-2	"	"	"	"	"	"	90	"	"	9.0	100	1.1	"	13.73	370	330	410	350	170	1370 / 1370	210	1100	"

TEST CONDITION: Thermal Reactor
IGNITION TIMING: 22° BTDC
ENGINE HP: 156.2 / 159.8

O-200 ENGINE EMISSION DATA

DATE: SEPT 20, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.10 / 29.10 in. Hg

RUN No	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		M.M.	D.R.	C.B.	THC PPM-C	Co %	Nox PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
4-4	*	16.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
5-1	1100	11.5	11.60	11.0	4,120	12.71	38	8.52	1.25	.165	8.53	.005	21.1	1093	.64	.0251	1.31	.0007	.011	.559	.00032
5-2	"	13.2	12.99	12.0	4,310	10.89	30	8.42	2.90	.162	8.31	.0032	20.1	1066	.48	.0251	1.28	.0006	.011	.534	.00025
5-3	"	14.7	14.60	13.9	1,040	4.15	34	12.12	1.80	.0504	4.07	.0054	6.5	522	.70	.0078	.63	.00084	.0024	.271	.00035
5-4	"	16.2	16.32	15.5	160	1.66	38	13.45	2.60	.0089	1.83	.0062	1.2	235	.87	.0014	.28	.00105	.0006	.122	.00045
6-1	1095	13.0	12.22	12.6	2,915	7.54	66	10.22	2.15	.113	5.93	.0085	14.7	872	1.25	.0175	.91	.00131	.0076	.395	.00056
6-2	"	13.2	13.61	12.9	2,515	7.14	53	10.44	2.70	.109	5.58	.0068	16.0	820	1.00	.0168	.56	.00104	.0073	.372	.00045
6-3	"	14.7	14.60	14.0	2,515	6.61	74	10.74	2.30	.092	5.10	.0094	14.2	751	1.32	.0148	.79	.00145	.0064	.340	.00062
6-4	"	16.2	16.60	15.1	495	2.62	55	12.93	2.5	.023	2.41	.0082	3.3	354	1.22	.0035	.37	.00128	.0015	.161	.00055
7-1	1706	10.0	10.00	9.8	6,855	12.53	26	7.34	.5	.655	24.7	.0083	26.8	991	.34	.0276	1.02	.00035	.0055	.201	.00006
7-2	"	13.2	13.19	13.3	460	3.26	41	12.57	.4	.071	10.39	.0209	2.9	425	.86	.003	.44	.00088	.0006	.865	.00017
7-3	"	14.7	15.60	14.7	85	1.24	42	13.37	1.6	.014	6.03	.0226	.6	247	.93	.0006	.25	.00095	.0001	.0502	.00015
7-4	"	16.2	16.70	16.3	70	1.58	36	13.50	2.2	.013	5.30	.0201	.5	218	.82	.00055	.22	.00085	.0001	.0443	.00016
8-1	1702	11.5	11.53	11.1	3,415	10.78	75	8.56	.55	.34	21.69	.0249	17.7	1130	1.55	.0144	.92	.00165	.0028	.181	.0002
8-2	"	13.2	13.72	12.8	315	4.71	74	11.85	.4	.072	11.61	.0292	3.8	605	1.62	.0031	.49	.00126	.0006	.097	.00024

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 156.2 / 159.8

0-200 ENGINE TEST DATA

DATE : SEPT 30, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
8-3	1050	1702	73	18.93	1700	11.5:1	100	52.1	80	12.5	110	1.7	19.2	14.7	370	330	410	380	170	1500 / 1460	210	1420	33.0
8-4	"	"	"	"	"	"	110	"	"	19.5	125	2.1	"	16.26	370	330	410	380	175	1510 / 1480	210	1440	"
9-1	1030	1705	"	18.82	"	13:1	0	51.0	78	–	–	0.5	16.8	12.99	390	345	430	400	155	1205 / 1205	210	890	34.0
9-2	"	"	"	"	"	"	90	"	"	.65	77	.5	"	13.17	390	345	430	400	160	1240 / 1240	215	905	"
9-3	"	"	"	"	"	"	100	"	"	3.0	90	1.0	"	15.23	390	345	430	390	160	1385 / 1385	215	1140	"
9-4	"	"	"	"	"	"	110	"	"	10.5	105	1.3	"	16.04	385	345	430	400	165	1430 / 1420	215	1270	"
10-1	1345	1953	96	22.72	1950	10:1	0	75.9	90	–	–	1.2	31.3	9.75	390	360	430	420	190	1150 / 1170	225	990	35.0
10-2	"	"	"	"	"	"	90	"	"	24.0	145	3.2	"	13.90	385	350	425	405	190	1560 / 1535	220	1510	"
10-3	"	"	"	"	"	"	100	"	"	32.0	160	3.8	"	15.39	385	350	425	405	190	1615 / 1600	225	1680	"
10-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1320	1754	96	21.54	"	11.5:1	0	71.1	86	–	–	1.0	25.2	11.75	410	370	465	450	180	1270 / 1265	225	1005	35.0
11-2	"	"	"	"	"	"	90	"	"	10.0	115	1.8	"	13.65	405	365	460	435	185	1395 / 1350	220	1230	"
11-3	"	"	"	"	"	"	100	"	"	16.0	125	2.2	"	14.87	405	365	455	435	185	1470 / 1450	225	1500	"
11-4	"	"	"	"	"	"	110	"	"	32.0	145	2.2	"	16.20	410	270	465	450	190	1490 / 1490	230	1560	"
12-1	1320	1955	"	21.56	"	13:1	0	70.2	80	–	–	0.7	22.6	13.20	410	370	470	440	175	1270 / 1265	210	1005	36.0

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 23° B.T.D.C.
ENGINE BHP: 156.2 / 159.2

0-200 ENGINE EMISSION DATA

DATE: SEPT. 30, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
8-3	1702	14.7	14.70	14.2	95	1.45	71	13.56	1.6	.0124	3.90	.0311	.64	203	1.62	.0005	.165	.0013	.0001	.0325	.00025
8-4	"	16.2	16.76	15.6	22	.62	78	13.98	2.2	.0030	1.72	.0351	.15	89	1.83	.00013	.073	.0015	.00002	.0143	.00029
9-1	1705	13.0	12.99	12.4	2,290	5.74	315	11.19	.6	.226	11.54	.103	13.45	682	6.13	.0095	.48	.0044	.0019	.0954	.00085
9-2	"	13.2	13.17	12.8	1,580	5.51	312	11.52	.95	.154	10.89	.1012	9.20	648	6.02	.0065	.46	.0043	.0013	.091	.00084
9-3	"	14.7	15.23	14.3	350	1.36	272	13.58	.70	.0403	2.17	.1041	2.40	189	6.20	.0017	.134	.0044	.0003	.0264	.00086
9-4	"	16.2	16.02	15.2	10	.36	229	14.11	1.85	.0011	.84	.0885	.06	50	5.27	.00005	.036	.0037	-	.007	.00071
10-1	1953	10.0	9.95	9.9	5,970	12.82	31	7.26	.8	.725	31.59	.0123	23.17	1009	.39	.0203	.88	.00035	.0725	3.16	.00123
10-2	"	13.2	13.9	13.5	435	4.06	42	12.22	1.2	.087	16.39	.0275	2.78	574	.85	.0025	.46	.00077	.0087	1.64	.00275
10-3	"	14.7	15.39	14.7	140	1.86	45	13.35	1.55	.0284	7.65	.020	.91	244	.92	.0008	.214	.00084	.00284	.765	.0030
10-4	—	16.2	—	—	—	—	—	—	—	—	—	—	-	-	—	—	—	—	—	—	—
11-1	1954	11.5	11.75	11.4	2,720	9.75	128	9.16	1.1	.352	25.84	.050	14.20	1025	2.22	.010	.72	.00157	.036	2.58	.0050
11-2	"	13.2	13.65	13.1	545	4.99	90	11.74	1.15	.085	15.78	.0465	3.37	626	1.85	.0024	.442	.0013	.0085	1.58	.00465
11-3	"	14.7	14.27	14.5	160	2.13	72	13.21	1.40	.0272	7.32	.0403	1.08	290	1.60	.00076	.205	.00113	.0027	.732	.00403
11-4	"	16.2	16.2	15.4	16	.95	75	13.72	1.45	.0027	3.21	.0416	.11	127	1.65	.00007	.040	.00117	.0003	.321	.00416
12-1	1955	13.0	13.2	[illegible]	2,285	6.77	281	10.68	.75	.304	18.19	.1740	13.46	805	5.49	.0085	.51	.00347	.0304	1.82	.0124

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 156.2 / 159.2

O-200 ENGINE TEST DATA

DATE: SEPT 30, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.10 / 29.10 in HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
12-2	1320	1955	96	21.50	1950	13:1	90	70.2	80	3.0	85	1.2	22.6	13.83	415	380	480	435	185	1395 / 1350	220	1100	36.0
12-3	"	"	"	"	"	"	100	"	"	7.0	105	1.6	"	14.70	420	380	470	455	190	1470 / 1450	230	1330	"
12-4	"	"	"	"	"	"	110	"	"	13.5	120	2.0	"	16.02	420	385	480	455	190	1490 / 1480	230	1420	"
13-1	1435	2755	130	28.15	2750	10:1	0	141.2	104	–	–	2.9	55.5	9.93	535	475	520	465	245	/	295	1170	33.0
13-2	"	"	120	"	"	"	90	"	"	40.0	210	3.8	"	13.57	535	465	520	435	245	/	290	1720	"
13-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	1425	2753	137	28.15	"	11.5:1	0	139.2	102	–	–	2.7	47.6	11.50	550	490	600	550	235	1330 / 1360	290	1250	32.0
14-2	"	"	132	"	"	"	90	"	"	21.0	160	3.2	"	13.26	550	490	585	535	240	1520 / 1530	290	1430	"
14-3	"	"	127	"	"	"	100	"	"	34.0	180	3.8	"	15.16	545	480	580	540	245	1640 / 1580	295	1690	"
14-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1415	2746	145	28.15	"	13:1	0	138.5	76	–	–	2.6	42.1	13.22	535	485	620	570	205	1405 / 1440	280	1265	31.0
15-2	"	"	139	"	"	"	90	"	"	5.0	115	3.5	"	13.83	535	485	620	570	215	1530 / 1530	290	1360	"
15-3	"	"	137	"	"	"	100	"	"	14.0	135	3.8	"	14.49	550	490	620	570	220	1580 / 1575	290	1505	"
15-4	"	"	128	"	"	"	110	"	"	20.0	170	3.8	"	15.68	550	470	620	570	235	1610 / 1560	290	1595	"

TEST CONDITION : THERMAL REACTOR
IGNITION TIMING: 23° BTDC
ENGINE BHP: 156.2 / 159.8

O-200 ENGINE EMISSION DATA

DATE : SEPT 30, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.10 / 29.10 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C. B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
12-2	1955	13.2	13.23	12.9	860	4.83	262	11.79	.55	.121	13.75	.123	5.35	608	5.43	.0034	.325	.00343	.0121	1.375	.0123
12-3	"	14.7	14.7	14.0	160	2.11	224	13.22	.55	.024	6.50	.113	1.07	288	5.02	.0007	.122	.00317	.0024	.65	.0113
12-4	"	16.2	16.05	14.9	40	.70	244	13.94	1.0	.0062	2.25	.128	.27	100	5.67	.0002	.063	.0036	.0006	.225	.0128
13-1	2755	10.0	9.93	10.4	7,260	12.16	68	7.49	1.5	1.622	54.85	.051	29.23	988	.91	.0232	.80	.00074	.00811 .1352	.274 4.57	.00025 .00421
13-2	"	13.2	13.57	13.4	1,980	3.89	84	12.24	.9	.373	27.11	.096	6.71	482	1.72	.0059	.431	.00152	.00186 .0310	.136 2.26	.00047 .008
13-3	-	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-4	-	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-1	2753	11.5	11.50	11.5	2,350	10.04	178	9.04	1.7	.581	50.11	.146	12.76	1053	3.07	[illegible]	.70	.00203	.0029 .0484	.251 4.18	.00073 .0122
14-2	"	13.2	13.26	12.8	710	6.00	161	11.22	1.35	.214	26.56	.161	4.49	768	3.32	.0031	.528	.00233	.0011 .018	.123 3.05	.0008 .0134
14-3	"	14.7	15.16	14.5	170	1.85	149	13.35	1.15	.053	11.74	.115	1.12	247	3.26	.0002	.176	.00233	.00026 .0044	.059 .98	.00057 .0096
14-4	-	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-1		13.0	13.22	12.8	1,720	5.93	516	11.16	1.3	.433	30.15	.432	10.29	716	10.26	.0057	.40	.00576	.00216 .0361	.151 2.51	.00215 .036
15-2	2746	13.2	13.83	13.5	490	4.32	477	12.09	1.3	.128	22.91	.417	3.04	546	9.90	.0018	.316	.00574	.00064 .01067	.115 1.92	.0021 .035
15-3	"	14.7	14.69	14.0	230	2.91	326	12.81	1.15	.066	16.95	.313	1.56	403	7.42	.0009	.237	.00436	.00022 .0035	.085 1.42	.00156 .026
15-4	"	16.2	15.68	15.1	32	.69	390	13.95	1.30	.009	3.87	.361	.21	92	8.52	.0002	.091	.0085	.00004 .00071	.019 .322	.0018 .030

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 152.8 / 153.8

0-200 ENGINE TEST DATA

DATE: Oct 4, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.50 / 29.50 in HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
1-1	1700	900°	21	13.46	900	10:1	0	18.9	84	–	–	0.2	7.85	10.22	250	210	265	240	130	775 850	135	470	33.0
1-2	*	*	*	*	"	"	90	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1-3	*	*	*	*	"	"	100	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1-4	1700	900	21	13.46	"	"	110	18.9	84	2.4	90	1.8	7.3	16.57	250	210	265	240	130	860 1470	135	515	33.0
2-1	1635	900	21	12.44	"	11.5:1	0	16.7	84	–	–	.2	6.15	11.54	250	210	265	240	140	825 850	140	420	32.5
2-2	"	"	"	"	"	"	90	"	"	2.6	95	.2	"	14.06	250	210	265	240	140	800 890	135	440	33.0
2-3	"	"	"	"	"	"	100	"	"	5.3	95	.3	"	16.12	250	210	265	240	135	850 1050	135	525	"
2-4	"	"	"	"	"	"	110	"	"	6.9	95	.5	"	17.46	250	210	265	240	135	1000 1200	135	650	"
3-1	1620	900	21	12.44	"	13:1	0	16.2	88	–	–	.2	5.15	13.18	270	230	285	265	170	265 900	145	490	30.5
3-2	"	"	"	"	"	"	90	"	"	.5	90	.2	"	13.60	260	225	280	255	160	850 890	140	450	31.0
3-3	"	"	"	"	"	"	100	"	"	2.2	90	.2	"	15.02	260	225	280	255	150	840 915	140	460	31.5
3-4	"	"	"	"	"	"	110	"	"	3.7	90	.3	"	16.47	260	225	280	255	150	990 1060	140	520	32.0
4-1	1810	1100	31	13.98	1100	10:1	0	25.6	88	–	–	.2	10.35	10.30	275	235	295	265	145	995 1040	145	630	33.0
4-2	*	*	*	*	"	"	90	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-3	*	*	*	*	"	"	100	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 18° BTDC
ENGINE [illegible]: 159.8 / 167.8

0-200 ENGINE EMISSION DATA

DATE: Oct 4, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
1-1	900	10.0	10.23	10.4	17,580	11.27	8.5	7.10		.57	7.38	.0009	78.1	1010	.12	.158	2.05	.00025	.114	1.48	.0002
1-2	*	13.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1-3	*	14.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
1-4	900	16.2	16.57	16.5	3,550	5.6	35	11.23	6.2	.149	4.74	.0048	20.4	650	.66	.041	1.32	.00135	.03	.95	.001
2-1	900	11.5	11.54	11.2	7,075	10.96	22	8.30	2.1	.205	6.40	.0021	35.0	1095	.36	.057	1.78	.0006	.041	1.28	.0004
2-2	"	13.2	14.06	14.0	5,990	10.44	22	8.67	5.75	.167	5.89	.0020	28.6	1007	.35	.047	1.64	.0006	.034	1.13	.00054
2-3	"	14.7	16.12	15.7	3,595	7.07	25	10.60	6.0	.117	4.62	.0027	17.9	790	.45	.032	1.28	.0007	.023	.92	.00069
2-4	"	16.2	17.46	17.0	1,225	3.49	27	12.62	5.5	.045	2.55	.0032	7.6	436	.55	.013	.71	.0009	.009	.51	.0018
3-1	900	13.0	13.16	12.8	3,209	6.83	59	10.76	2.0	.094	4.05	.0057	12.2	756	1.11	.026	1.12	.0016	.019	.81	.0009
3-2	"	13.2	13.60	13.6	3,250	6.58	51	10.38	3.4	.078	4.10	.0045	16.9	795	.86	.024	1.14	.00125	.017	.82	.0009
3-3	"	14.7	15.02	15.0	3,125	6.54	49	10.91	4.8	.088	3.70	.0045	17.0	719	.88	.025	1.03	.00125	.017	.74	.0015
3-4	"	16.2	16.47	16.3	2,130	4.78	69	11.89	4.3	.071	3.18	.0075	13.7	617	1.45	.0195	.88	.0021	.014	.636	.00007
4-1	1100	10.0	10.30	10.2	7,790	12.62	9	7.27	1.3	.316	10.37	.0012	30.7	1007	.12	.049	1.60	.0002	.021	.69	.0007
4-2	"	13.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
4-3	"	14.7	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 15° BTDC
ENGINE HRS: 151.8 / 167.8

0-200 ENGINE TEST DATA

DATE: Oct 4, 1972
REL. HUMIDITY: 50 % / 50 %
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
4-4	1810	1100	31	13.98	1100	10:1	110	25.6	88	12.0	110	.9	10.35	15.67	275	235	295	265	145	1530 1600	150	1230	33.0
5-1	1830	1103	31	12.26	"	11.5:1	0	21.8	90	–	–	.2	7.85	11.55	275	235	295	265	155	940 970	155	540	33.0
5-2	"	"	"	"	"	"	90	"	"	3.0	100	.4	"	13.52	275	235	295	265	155	970 1180	150	575	"
5-3	"	"	"	"	"	"	100	"	"	5.0	100	.7	"	14.67	275	235	295	265	160	1140 1360	150	770	"
5-4	"	"	"	"	"	"	110	"	"	7.5	100	.8	"	16.61	275	235	295	265	160	1340 1485	150	890	"
6-1	1750	1101	31	12.60	"	13:1	0	22.4	92	–	–	.2	7.1	13.03	290	255	310	285	175	940 990	155	540	31.0
6-2	"	"	"	"	"	"	90	"	"	3.5	100	.4	"	13.40	290	255	310	285	170	770 1010	155	525	31.5
6-3	"	"	"	"	"	"	100	"	"	6.4	100	.7	"	14.77	290	255	310	285	165	1080 1160	155	570	32.0
6-4	"	"	"	"	"	"	110	"	"	9.0	100	1.1	"	16.16	290	255	310	285	160	1310 1290	155	650	32.5
7-1	1600	1700	73	20.71	1700	10:1	0	52.7	92	–	–	.8	23.9	10.19	375	320	390	375	180	1150 1180	160	890	32.5
7-2	"	"	"	"	"	"	90	"	"	13.0	125	2.0	"	13.20	375	320	390	375	180	1540 1520	160	1400	33.5
7-3	"	"	"	"	"	"	100	"	"	22.0	140	2.8	"	14.78	375	320	405	275	180	1600 1580	160	1560	33.5
7-4	"	"	"	"	"	"	110	"	"	27.5	160	3.8	"	15.90	380	325	405	380	185	1710 1630	165	1670	33.0
8-1	1550	1702	73	19.17	"	11.5:1	0	54.4	92	–	–	.7	19.3	11.65	385	340	420	385	175	1195 1215	170	900	33.5
8-2	"	"	"	"	"	"	90	"	"	9.5	110	1.1	"	13.26	385	340	420	385	175	1440 1450	175	1190	"

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 132.8 / 167.9

0-200 ENGINE EMISSION DATA

DATE: OCT 4, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN NO	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM	DIP	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
4-4	1106	16.2	15.67	15.4	125	.05	8	14.0	1.9	.0082	1.28	.0017	1.8	124	.17	.0013	.197	.00027	.00054	.085	.00011
5-1	1103	11.5	11.55	11.3	4,465	[illegible]	36	8.77	1.6	.1631	7.84	.0043	22.2	1067	.54	.0351	1.20	.00066	.0109	.523	.00029
5-2	"	13.2	13.52	13.1	2,650	5.25	35	10.10	3.0	.101	6.36	.0044	13.8	865	.60	.0155	.98	.00057	.0067	.424	.00029
5-3	"	14.7	14.67	14.3	740	3.42	37	12.7	1.8	.033	3.07	.0054	4.5	413	.74	.005	.47	.00089	.0022	.205	.00035
5-4	"	16.2	16.51	16.1	75	.89	42	14.04	2.7	.0025	.85	.0065	.5	116	.87	.0005	.13	.001	.00023	.057	.00043
6-1	1101	13.0	13.03	12.2	2,895	8.24	57	10.08	1.6	.110	6.23	.0072	16.2	931	1.05	.017	.97	.0011	.0073	.422	.00017
6-2	"	13.2	13.40	12.9	2,780	7.84	56	10.77	2.55	.103	5.81	[illegible]	15.1	859	1.00	.0158	.90	.00105	.0068	.389	.00015
6-3	"	14.7	14.77	14.3	1,305	4.97	57	11.87	2.8	.052	4.07	.0077	7.9	599	1.13	.0053	.63	.0012	.0026	.271	.00031
6-4	"	16.2	16.12	15.8	270	1.90	56	13.51	2.9	.012	1.69	.0083	1.7	250	1.21	.0018	.26	.0013	.0008	.113	.00055
7-1	1700	10.0	10.19	10.1	6,105	12.47	27	7.65	.80	.776	23.75	.0086	[illegible]	1019	.27	.0244	1.01	.00036	.0048	.198	.00007
7-2	"	13.2	13.20	13.0	970	4.21	41	12.29	.50	.132	11.54	.0185	5.7	495	.80	.0056	.47	.0008	.0011	.096	.00015
7-3	"	14.7	14.78	14.1	275	2.43	43	13.25	1.0	.042	7.50	.022	1.8	322	.95	.0018	.32	.0009	.00024	.0625	.00018
7-4	"	16.2	15.80	15.3	25	1.92	38	13.52	2.25	.004	6.74	.0702	.2	260	.87	.0002	.265	.00025	.00003	.052	.00015
8-1	1702	11.5	11.65	11.4	3,070	10.22	64	9.07	.85	.300	20.15	.0208	15.5	1044	1.08	.0177	.85	.0009	.0025	.168	.00017
8-2	"	12.2	[illegible]	13.6	845	[illegible]	71	[illegible]	.65	[illegible]	6.79	[illegible]	[illegible]	[illegible]	1.71	[illegible]	.28	.0011	[illegible]	.055	[illegible]

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: [illegible]
ENGINE HRS: 159.8 / 167.8

0-200 ENGINE TEST DATA

DATE: Oct 4, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
8-3	1550	1702°	72	19.17	1700	11.5:1	100	54.4	92	16.5	120	1.6	19.3	15.44	385	340	420	385	180	1520 1500	175	1360	33.5
8-4	"	"	"	"	"	"	110	"	"	28.5	130	2.5	"	16.30	385	340	420	385	180	1575 1530	175	1390	"
9-1	1520	1703	72	19.39	"	13:1	0	51.2	85	–	–	.7	16.3	13.30	390	340	425	390	160	1230 1245	170	895	34.5
9-2	"	"	"	"	"	"	90	"	"	1.3	85	.7	"	12.46	390	340	425	390	165	1300 1280	175	925	"
9-3	"	"	"	"	"	"	100	"	"	8.0	95	1.5	"	15.63	390	340	425	390	170	1430 1450	175	1200	34.0
9-4	"	"	"	"	"	"	110	"	"	10.5	115	1.7	"	16.10	400	350	430	405	175	1470 1480	175	1290	"
10-1	1735	1950	96	23.92	1950	10:1	0	82.6	90	–	–	1.3	33.3	10.00	410	360	430	415	195	1215 1230	180	1040	37.0
10-2	"	"	"	"	"	"	90	"	"	22.0	160	3.7	"	13.65	410	360	420	410	195	1620 1625	180	1630	"
10-3	"	"	"	"	"	"	100	"	"	31.0	180	3.9	"	14.14	410	360	420	410	200	1650 1680	180	1710	"
10-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1730	1950	96	22.00	"	11.5:1	0	74.0	96	–	–	1.0	26.0	11.64	420	370	455	430	190	1260 1270	185	1020	34.0
11-2	"	"	"	"	"	"	90	"	"	11.5	125	1.9	"	13.27	420	370	455	430	190	1550 1575	185	1350	33.5
11-3	"	"	"	"	"	"	100	"	"	19.5	140	2.9	"	15.16	420	370	455	420	195	1560 1545	185	1520	33.0
11-4	"	"	"	"	"	"	110	"	"	24.0	155	3.9	"	15.47	420	370	455	[illegible]	200	1620 1590	190	1595	"
12-1	1720	1950	96	21.21	"	13:1	0	72.6	90	–	–	.3	23.1	12.08	445	370	450	420	155	1310 1315	170	1020	36.5

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 18° BTDC
ENGINE HP: 159.8 / 167.9

0-200 ENGINE EMISSION DATA

DATE: Oct 4, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN No	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
8-3	1702	14.7	15.44	15.3	130	.62	92	14.17	.2	.015	1.42	.036	.84	81	1.97	.00064	.062	.0015	.00012	.0122	.0003
8-4	"	16.2	16.50	16.7	44	.29	76	14.79	1.2	.005	.91	.029	.18	51	1.60	.0021	.023	.00122	.00004	.0076	.00071
9-1	1703	13.0	13.00	12.6	2,205	6.67	265	10.92	1.5	.291	13.91	.086	13.05	795	5.16	.00922	.55	.00355	.0013	.108	.0037
9-2	"	13.2	13.16	13.0	1,450	7.66	264	11.52	1.35	.137	11.01	.085	7.58	426	5.18	.0159	.465	.00357	.00115	[illegible]	.0007
9-3	"	14.7	15.63	14.3	125	1.71	220	13.62	.75	.014	3.92	.083	.27	241	5.07	.0006	.166	.0025	.00011	.033	.0007
9-4	"	16.2	16.18	15.3	34	.51	187	14.23	1.45	.004	1.18	.071	.24	73	4.34	.00016	.150	.003	.00003	.0098	.0006
10-1	1950	10.0	10.03	9.8	4,675	13.42	32	7.21	.4	.595	34.49	.014	17.25	1035	.41	.0171	.99	.0004	.0595	3.45	.0014
10-2	"	13.2	13.65	13.6	615	2.37	46	12.75	.9	.118	13.04	.029	[illegible]	392	.87	.0075	.326	.0002	.0115	1.31	.0029
10-3	"	14.7	14.86	14.7	385	2.55	47	13.12	2.0	.078	10.55	.032	2.25	317	.95	.0022	.396	.0009	.0078	1.04	.0022
10-4	"	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1953	11.5	11.64	10.8	2,830	11.39	77	8.51	.7	.378	30.73	.034	14.55	1182	1.31	.0156	.86	.00095	.0379	3.07	.0034
11-2	"	13.2	12.27	12.7	435	4.9	84	12.00	.3	.070	15.96	.045	2.70	614	4.55	.0027	.423	.00315	.007	1.60	.0045
11-3	"	14.7	15.16	13.9	160	2.2	70	13.30	.65	.028	7.67	.040	1.06	295	1.54	.00077	.215	.00112	[illegible]	.77	[illegible]
11-4	"	16.2	16.47	15.9	30	.27	66	14.05	2.5	.005	2.99	.037	.19	115	1.43	.00014	.024	.001	.0005	.35	.0027
12-1	1950	13.0	13.08	12.3	2,065	7.10	202	10.57	.7	.212	19.12	.077	[illegible]	828	[illegible]	.00514	.57	.0026	.274	19.1	.692

TEST CONDITION: Thermal Reactor
IGNITION TIMING: [illegible]
ENGINE HRS: [illegible] / [illegible]

0-200 ENGINE TEST DATA

DATE: Oct 4, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
12-2	1720	1950°	96	21.81	1750	13:1	90	72.6	90	2.5	105	1.1	23.1	13.77	420	370	455	440	160	[illegible] / [illegible]	120	1160	26.0
12-3	"	"	"	"	"	"	100	"	"	8.0	115	1.8	"	14.75	425	380	470	450	170	1500 / 1515	155	1240	25.5
12-4	"	"	"	"	"	"	110	"		12.5	130	2.6	"	15.77	425	380	470	450	175	1530 / 1550	185	1460	29.0
13-1	1020	2753	133	28.43	2750	10:1	0	143.0	110	–	–	3.0	54.3	10.[illegible]	555	465	470	460	250	[illegible] / [illegible]	260	1230	30.5
13-2	"	"	125	"	"	"	90	"	"	34.0	210	3.9	"	13.29	555	465	470	460	250	1700 / 1660	260	1760	30.5
13-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	"	"	110	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–
14-1	1900	2745	145	28.43	"	11.5:1	0	141.0	110	–	–	2.9	48.0	11.36	555	475	580	520	245	1360 / 1410	265	1290	31.5
14-2	"	"	139	"	"	"	90	"	"	27.5	170	3.9	"	13.55	555	475	570	500	245	1560 / 1570	265	1450	31.0
14-3	"	"	130	"	"	"	100	"	"	40.0	200	3.9	"	15.50	565	475	570	495	250	1680 / 1630	265	1710	30.5
14-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1845	2750	148	28.43	"	13:1	0	141.0	102	–	–	2.9	45.1	13.04	525	460	590	535	195	1430 / 1490	220	1295	37.0
15-2	"	"	143	"	"	"	90	"	"	6.0	120	3.3	"	13.73	545	470	610	550	205	1550 / 1550	230	1390	36.0
15-3	"	"	142	"	"	"	100	"	"	17.5	150	3.9	"	15.11	545	470	610	550	220	1570 / 1590	260	1430	34.0
15-4	"	"	135	"	"	"	110	"	"	28.5	190	3.9	"	16.07	560	480	610	550	235	1640 / 1645	265	1635	31.5

TEST CONDITION: THERMAL REACTOR
IGNITION TIMING: 18° BTDC
ENGINE HRS: 159.8 / 167.8

0-200 ENGINE EMISSION DATA

DATE : Oct 4, 1972
REL. HUMIDITY: 50% / 50%
BARO. PRESSURE: 29.50 / 29.50

RUN No	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM C	Co %	Nox PPM	CO₂ %	O₂ %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
12-2	1950	13.2	13.37	12.8	640	5.02	227	11.92	.6	.089	14.14	.105	2.26	412	4.57	.00053	.226	.0022	.029	1.41	.0165
12-3	"	14.7	14.75	13.8	125	2.28	199	13.34	.35	.020	7.35	.1055	.84	312	2.59	.00026	.161	.0028	.002	.74	.0165
12-4	"	16.2	15.77	15.3	45	.63	170	14.17	1.55	.007	1.92	.086	.29	93	3.72	.00017	.054	.0024	.0007	.192	.0056
13-1	2753	10.0	10.18	10.1	5,870	11.53	68	8.14	.35	1.31	51.97	.050	24.12	957	.92	.0187	.75	.0007	.0065 .139	.260 4.33	.00335 .00416
13-2	"	13.2	13.29	13.7	550	3.05	100	12.91	.75	.17	10.54	.105	3.21	360	1.93	.0027	.30	.0016	.0009 .0145	.0777 1.628	.00052 .00573
13-3	"	14.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–
13-4	"	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	2745	11.5	11.36	10.8	2,770	10.56	147	8.93	.4	.676	51.07	.117	14.08	1083	2.48	.0039	.69	.0016	.0034 .0563	.26 4.33	.0006 .0110
14-2	"	13.2	13.55	13.0	960	6.85	132	10.97	.3	.276	40.52	.129	5.76	850	2.60	.0038	.561	.0019	.0014 .0263	.201 3.40	.00068 .0167
14-3	"	14.7	15.50	14.7	180	1.99	130	13.48	1.55	.057	12.46	.134	1.18	260	2.79	.00033	.183	.002	.0003 .0047	.052 1.64	.00066 .0111
14-4	"	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	2750	13.0	13.04	12.1	1,370	6.80	313	10.96	.4	.240	34.06	.257	7.88	790	5.97	.0044	.44	.0033	.0017 .0283	.170 2.84	.0013 .0214
15-2	"	13.2	13.73	12.8	570	4.61	393	12.13	.3	.150	24.46	.343	3.48	567	7.95	.002	.327	.0046	.00075 .0125	.122 2.04	.0017 .0285
15-3	"	14.7	15.11	14.5	330	3.78	269	12.57	.25	.094	21.92	.257	2.19	508	5.05	.0013	.245	.0035	.0005 .473	.110 1.83	.0012 .0214
15-4	"	16.2	16.07	15.5	90	.96	310	14.00	1.65	.024	5.73	.362	.55	133	7.03	.00052	.081	.0043	.0011 .01136	.019 .478	.0015 .0250

APPENDIX B5
CATALYTIC CONVERTOR EVALUATION

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 177.2 / 192.5

0-200 ENGINE TEST DATA

DATE: Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CAT.	COWLING	EXH. GAS	
1-1	1455	905*	21	12.99	900	10:1	0	17.3	76	—	—	—	7.3	10.35	255	210	260	225	[illegible]	570 550	130	[illegible]	33.0
1-2	"	"	"	"	"	"	90	"	"	5.2	75	0.6	"	13.53	245	210	260	235	130	1270 1230	125	[illegible]	"
1-3	"	"	"	"	"	"	100	"	"	7.2	75	[illegible]	"	14.10	245	210	260	235	130	1250 1270	125	1180	"
1-4	"	"	"	"	"	"	110	"	"	9.1	75	0.8	"	16.17	245	210	260	235	130	720 [illegible]	125	1110	32.5
2-1	1440	902	"	12.26	"	11.5:1	0	15.5	76	—	—	—	5.75	11.66	240	200	260	230	130	470 520	125	450	33.0
2-2	"	"	"	"	"	"	90	"	"	2.3	75	0.1	"	13.92	240	200	260	230	130	510 670	125	590	33.5
2-3	"	"	"	"	"	"	100	"	"	4.2	85	0.3	"	15.48	225	200	250	220	130	1110 1050	125	1030	"
2-4	"	"	"	"	"	"	110	"	"	5.9	85	0.5	"	16.51	240	200	250	220	130	1210 1180	125	1180	"
3-1	1430	900	"	12.24	"	13:1	0	15.5	80	—	—	—	4.95	13.06	260	210	270	240	140	760 670	130	620	33.0
3-2	"	"	"	"	"	"	90	"	"	0.5	85	0.1	"	13.93	260	210	270	240	135	810 710	130	660	"
3-3	"	"	"	"	"	"	100	"	"	2.0	85	0.1	"	15.23	260	210	270	240	135	750 810	130	790	"
3-4	"	"	"	"	"	"	110	"	"	3.6	95	0.2	"	16.71	260	210	270	240	135	1030 970	125	870	"
4-1	1120	1095	31	13.44	1100	10:1	0	20.0	76	—	—	—	8.60	10.16	260	215	270	240	130	610 630	130	550	34.0
4-2	"	"	"	"	"	"	90	"	"	6.0	80	0.2	"	13.69	260	215	270	240	130	1190 1200	130	1270	"
4-3	"	"	"	"	"	"	100	"	"	9.0	85	[illegible]	"	15.17	260	215	270	240	130	1270 1220	130	1270	"

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE BHP: 177.2 / 182.5

O-200 ENGINE EMISSION DATA

DATE: Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO_2 %	O_2 %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
1-1	905	10.0	10.25	9.5	16,930	11.87	7	6.86	2.2	.501	7.10	.0007	68.7	972	.09	.139	1.96	.0002	.100	1.42	.00015
1-2	"	13.2	13.59	13.5	3,820	7.17	9	10.52	2.6	.146	5.54	.0011	20.0	758	.15	.04	1.53	.0003	.029	1.11	.00022
1-3	"	14.7	14.9	14.1	700	4.97	13	11.94	2.5	.032	4.54	.002	4.32	622	.27	.009	1.25	.0005	.006	.91	.0004
1-4	902	16.2	16.17	15.7	20	0.63	32	14.17	2.1	.001	.62	.0052	.13	85	.71	.0003	.17	.0014	.0002	.12	.001
2-1	"	11.5	11.66	11.3	8,660	10.16	24	8.54	2.0	.230	5.41	.0021	40.6	962	.38	.064	1.51	.0006	.046	1.09	.0004
2-2	"	13.2	13.92	13.0	3580	7.16	18	10.55	2.1	.987	3.99	.0016	17.6	712	.29	.027	1.11	.0005	.02	.80	.0003
2-3	"	14.7	15.02	15.1	300	1.37	7	13.78	2.1	.011	0.99	.0008	1.9	177	.15	.003	.28	.0002	.002	.20	.0002
2-4	900	16.2	16.91	16.6	50	0.11	28	14.43	3.1	.002	.08	.0026	.33	15	.64	.0005	.02	.001	.0004	.02	.0007
3-1	"	13.0	13.06	13.2	4390	5.75	38	11.15	2.2	.117	3.10	.0034	23.7	626	.69	.033	.26	.001	.023	.62	.0007
3-2	"	12.2	13.74	14.2	3,670	3.34	22	12.46	2.4	.101	1.86	.0029	20.4	375	.59	.028	.52	.0005	.02	.37	.0004
3-3	"	14.7	15.27	14.6	360	0.33	23	14.29	2.2	.109	.20	.0023	2.21	41	.47	.0003	.06	.0006	.002	.04	.0005
3-4	"	16.2	16.71	16.0	275	0.11	72	14.41	3.5	.009	.07	.0074	1.73	15	1.5	.0024	.02	.0021	.0017	.014	.0015
4-1	1098	10.0	10.16	10.4	7060	12.25	7	7.66	1.9	.257	9.01	.0009	30.8	1078	.11	.039	1.38	.00015	.0171	.60	.0005
4-2	"	13.2	13.69	14.2	71	3.30	5	12.83	2.2	.004	3.60	.001	.46	431	.12	.0006	.55	.00015	.0003	.24	.0006
4-3	"	14.7	15.37	15.6	15	1.10	27	13.94	2.5	.001	1.25	.005	.1	149	.60	.0001	.17	.0008	.0005	.02	.0003

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 137.2 / 137.5

0-200 ENGINE TEST DATA

DATE : Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
4-4	1120	1095	21	13.41	1100	10:1	110	20.0	76	[illegible]	[illegible]	0.5	8.60	17.04	260	215	270	240	130	1310 1270	135	1150	34.0
5-1	1100	1093	"	12.09	"	11.5:1	0	18.8	76	–	–	–	7.0	11.73	270	220	280	250	130	640 650	130	575	"
5-2	"	"	"	"	"	"	90	"	"	2.9	75	0.2	"	13.19	270	220	280	250	130	1055 1030	130	1065	"
5-3	"	"	"	"	"	"	100	"		4.6	75	0.3	"	14.70	270	220	280	250	130	1150 1120	130	1195	"
5-4	"	"	"	"	"	"	110	"	"	7.9	75	0.7	"	16.97	270	270	280	250	130	1160 1195	130	1150	"
6-1	1135	1099	"	12.2	"	13:1	0	19.1	76	–	–	–	6.4	13.03	280	230	295	260	130	740 720	135	650	"
6-2	"	"	"	"	"	"	90	"	"	0.7	75	0.1	"	13.82	280	230	295	260	130	750 [illegible]	135	690	"
6-3	"	"	"	"	"	"	100	"	"	2.6	75	0.2	"	14.86	280	230	295	260	130	1025 1020	135	950	"
6-4	"	"	"	"	"	"	110	"	"	4.7	75	0.5	"	16.74	280	230	295	260	130	1070 [illegible]	135	1000	"
7-1	1210	1702	73	17.0	1700	10:1	0	43.8	85	–	–	0.4	20.0	9.89	360	300	380	[illegible]	160	[illegible] [illegible]	160	840	35.0
7-2	"	"	"	"	"	"	90	"	"	18.0	110	1.2	"	13.97	360	305	380	335	160	1370 1350	160	1460	"
7-3	"	"	"	"	"	"	100	"	"	22.0	115	2.1	"	15.06	360	305	380	335	160	1570 1510	160	1670	"
7-4	"	"	"	17.64	"	"	110	"	"	27.0	135	2.5	"	16.76	360	305	380	[illegible]	160	1570 [illegible]	160	1630	"
8-1	1200	1702	"	17.64	"	11.5:1	0	47.7	82	–	–	0.4	18.0	11.34	385	320	405	365	160	870 860	165	880	"
8-2	"	"	"	"	"	"	90	"	"	9.0	95	0.7	"	13.61	380	310	405	360	160	1355 [illegible]	165	1300	"

TEST CONDITION : CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 172.2 / 182.5

0-200 ENGINE EMISSION DATA

DATE : Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55 IN HG.

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C. B	THC PPM-C	CO %	NOx PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
4-4	1098	16.2	17.24	16.9	6	.11	24	14.44	3.5	.0004	.12	.0046	.04	15	.56	.00006	.02	.0007	.00002	.008	.0003
5-1	1098	11.5	11.73	11.8	4,420	8.24	49	9.63	1.5	.145	5.86	.0053	20.7	836	.76	.0223	.90	.0008	.01	.39	.0004
5-2	"	13.2	13.29	14.0	3,350	2.83	42	12.74	1.6	.14	2.40	.0059	20.0	342	.84	.0215	.37	.0009	.009	.16	.0004
5-3	"	14.7	14.79	15.1	270	1.55	40	13.68	2.0	.016	1.37	.0057	2.33	196	.22	.0025	.21	.0009	.001	.09	.0009
5-4	"	16.2	16.97	16.4	120	.11	26	14.42	2.7	.006	.10	.0056	.87	15	.81	.0009	.016	.0009	.0002	.008	.0004
6-1	1009	13.0	13.03	12.6	3060	6.61	88	10.88	1.5	.118	5.13	.0113	18.29	802	1.76	.0181	.79	.0017	.0078	.34	.0008
6-2	"	13.2	13.82	14.1	2,520	3.57	72	12.45	2.0	.093	2.65	.009	14.47	414	1.38	.0143	.41	.0014	.0062	.18	.0006
6-3	"	14.7	14.86	15.3	140	.51	58	14.22	1.5	.006	.42	.008	.23	66	1.22	.0009	.065	.0012	.0004	.028	.0005
6-4	"	16.2	16.74	16.1	80	.11	66	14.43	2.2	.0025	.09	.01	.54	15	1.48	.0005	.014	.0015	.0002	.006	.0006
7-1	1702	10.0	9.59	10.2	6,420	12.48	21	7.61	1.0	.51	20.0	.005	24.28	957	.26	.0215	.845	.0023	.004	.17	.0004
7-2	"	13.2	13.89	13.4	150	3.19	7	12.88	.35	.019	8.07	.003	.89	386	.14	.0008	.341	.0001	.00015	.07	.0002
7-3	"	14.7	15.06	14.2	18	.35	23	14.31	1.15	.0025	.78	.01	.12	47	.50	.0001	.041	.0004	.00002	.008	.0008
7-4	"	16.2	16.76	15.3	7	.06	36	14.46	2.5	.0009	.15	.016	.04	7	.75	.00004	.006	.0007	—	.0012	.0001
8-1	1702	11.5	11.34	11.0	3,010	10.42	46	8.98	0.9	.27	18.9	.014	14.98	1050	.77	.0114	.8	.0006	.002	.157	.0001
8-2	"	13.2	12.61	13.0	145	4.56	11	[illegible]	0.35	.016	10.14	.004	.97	564	.21	.0007	.42	.0002	.0001	.031	.0002

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 177.2 / 182.5

0-200 ENGINE TEST DATA

DATE: Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
8-3	1200	1702	73	17.64	1700	11.5:1	100	47.7	82	15.0	105	1.1	18.0	15.23	320	310	400	360	160	1370 [illegible]	165	1440	35.0
8-4	"	"	"	"	"	"	110	"	"	21.0	105	1.7	"	16.91	320	310	400	360	160	1490 1420	165	1550	"
9-1	1150	1695	"	[illegible]	"	13:1	0	[illegible]	80	—	—	0.4	15.0	12.98	385	310	410	370	135	870 590	165	910	36.0
9-2	"	"	"	"	"	"	90	"	"	1.5	80	0.3	"	13.13	390	320	420	380	145	1010 1000	165	1040	35.5
9-3	"	"	"	"	"	"	100	"	"	8.0	90	0.7	"	15.43	390	320	420	380	150	1245 1215	170	1290	35.5
9-4	"	"	"	"	"	"	110	"	"	12.0	105	0.9	"	16.19	390	320	420	380	160	1330 1300	170	1390	35.0
10-1	1410	1955	96	20.95	1950	10:1	0	68.7	87	—	—	0.7	29.1	9.93	405	320	420	390	185	940 920	175	960	"
10-2	"	"	"	"	"	"	90	"	"	21.0	130	2.7	"	13.57	395	325	415	380	190	1610 1610	175	1710	"
10-3	"	"	"	"	"	"	100	"	"	30.0	140	3.8	"	15.46	395	325	415	320	190	1690 1625	175	1890	"
10-4	—	—	—	—	"	"	110	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11-1	1405	1954	96	20.51	"	11.5:1	0	65.9	87	—	—	0.7	24.0	11.55	430	345	455	420	175	970 955	180	1000	35.0
11-2	"	"	"	"	"	"	90	"	"	14.0	105	1.3	"	13.91	430	345	455	420	175	1325 1310	180	1405	"
11-3	"	"	"	"	"	"	100	"	"	18.0	135	1.8	"	14.77	430	345	455	420	175	1470 1445	180	1550	"
11-4	"	"	"	"	"	"	110	"	"	25.0	140	3.0	"	14.49	430	345	455	420	180	1550 1465	180	1590	"
12-1	1350	1954	"	[illegible]	"	12:1	0	[illegible]	85	—	—	0.7	[illegible]	[illegible]	440	350	470	430	140	1000 [illegible]	175	1030	37.0

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE HPS: 177.2 / 193.5

0-200 ENGINE EMISSION DATA

DATE: Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55 IN HG.

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	Co %	Nox PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
8-3	1702	14.7	15.23	14.2	17	2.67	7	13.47	0.35	.0022	5.09	.003	.12	282	.17	.00009	.215	.00012	.00001	.042	.00002
8-4	"	16.2	16.99	16.1	6	.21	44	14.39	2.45	.0008	.53	.0182	.04	30	1.02	.00003	.022	.0008	-	.0044	.00015
9-1	1695	13.0	12.95	12.7	1,620	5.89	176	11.38	1.15	.1414	9.53	.0511	9.43	693	3.41	.006	.441	.0022	.0012	.071	.00042
9-2	"	13.2	13.43	13.1	395	4.33	53	12.29	0.5	.035	7.81	.016	2.34	520	1.04	.0015	.331	.0007	.0003	.065	.0001
9-3	"	14.7	15.43	14.8	15	.74	141	14.12	0.9	.0015	1.53	.048	.10	103	3.20	.00006	.065	.002	.00001	.013	.0004
9-4	"	16.2	16.19	15.1	3	.39	160	14.29	1.1	.003	.27	.058	.02	58	3.87	.00001	.037	.0025	.00002	.0072	.0005
10-1	1955	10.0	9.93	10.2	4,710	12.33	23	7.85	0.75	.534	28.3	.009	18.36	970	.3	.015	.79	.00025	.053	2.8	.0009
10-2	"	13.2	13.57	13.7	15	2.30	11	13.24	0.4	.0026	8.5	.007	.09	293	.23	.00007	.24	.0002	.0003	.85	.0007
-10-3	"	14.7	15.46	14.7	3	.36	32	14.31	0.9	.0006	1.4	.0205	.02	48	.71	.00002	.04	.0006	.00004	.129	.0021
10-4	-	16.2	-	-	-	-	-	--	-	-	-		-	-	-	-	-	-	-	-	-
11-1	1954	11.5	11.55	11.5	2,790	9.08	84	9.62	1.0	.328	21.8	.033	13.7	909	1.36	.0092	.611	.0009	.033	2.18	.003
11-2	"	13.2	13.91	13.1	95	4.25	20	12.36	0.5	.015	13.5	.0106	.61	549	.43	.0004	.395	.0003	.0015	1.35	.0011
11-3	"	14.7	14.77	14.2	15	1.46	20	13.76	0.45	.0024	4.8	.0106	.10	197	.43	.00007	.136	.0003	.0002	.454	.0011
11-4	"	16.2	16.49	15.7	3	.11	94	14.44	2.2	.0005	.35	.0516	.02	15	2.10	.00001	.01	.0015	.00005	.035	.0052
12-1	1954	13.0	13.00	12.6	1,710	7.29	400	11.4	0.9	.221	15.13	.169	10.13	694	7.75	.0062	.424	.0005	.022	.151	.017

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE HRS: 172.2 / 183.5

O-200 ENGINE TEST DATA

DATE: Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55 IN HG

RUN Nº	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERTURE °F				OIL PRESS PSI
					PPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CORE	COWLING	EXH. GAS	
12-2	[illegible]	1950	90	[illegible]	1950	13:1	90	66.[illegible]	85	4.0	90	1.0	[illegible]	[illegible]	440	350	47[illegible]	[illegible]	155	12[illegible] 1[illegible]	175	1470	37.0
12-3	"	"	"	"	"	"	100	"	"	11.0	100	1.3	"	15.36	435	360	470	435	165	1370 1310	175	1400	36.0
12-4	"	"	"	"	"	"	110	"	"	16.0	110	1.5	"	16.04	445	360	480	450	165	1430 [illegible]	175	1470	35.0
13-1	1545	2750	155	28.50	2750	10:1	0	141.0	100	–	–	2.2	56.9	9.95	595	480	550	470	245	1120 1090	225	–	30.0
13-2	"	"	140	"	"	"	90	"	"	40.0	190	3.8	"	13.55	580	475	545	460	245	1700 1700	225	–	30.0
13-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	1540	2755	160	29.50	"	11.5:1	0	139.0	100	–	–	2.1	48.5	11.51	600	485	630	565	235	1100 1165	225	–	32.0
14-2	"	"	160	"	"	"	90	"	"	23.0	150	3.8	"	13.94	600	485	620	550	240	1460 [illegible]	225	–	31.5
14-3	"	"	155	"	"	"	100	"	"	36.0	170	3.8	"	15.31	600	485	620	540	240	1745 1665	225	–	31.0
14-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1530	2750	165	28.50	"	13:1	0	136.5	95	–	–	2.0	42.8	13.04	585	485	650	585	190	1480 1420	215	1540	32.5
15-2	"	"	165	"	"	"	90	"	"	3.0	155	2.6	"	13.22	595	485	620	585	205	1325 1200	215	–	36.0
15-3	"	"	160	"	"	"	100	"	"	16.0	125	3.3	"	14.24	600	495	620	585	215	1310 1200	215	–	35.0
15-4	"	"	155	"	"	"	110	"	"	30.0	170	3.8	"	16.20	600	485	620	585	[illegible]	[illegible] [illegible]	215	–	33.0

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 28° BTDC
ENGINE BHP: 177.2 / 182.5

0-200 ENGINE EMISSION DATA

DATE: Oct 12, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.55 / 29.55 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB /HR			LB /1000 lb FUEL			LB /BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	Co %	Nox PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
12-2	1954	13.2	13.34	13.4	210	4.02	185	12.43	0.95	.0282	11.1	.083	1.29	510	3.8	.0008	.311	.0023	.003	1.11	.0083
12-3	"	14.7	[illegible]	14.5	45	2.41	129	12.29	1.6	.0066	7.4	.065	.26	339	3.0	.0002	.207	.0018	.0007	.74	.0065
12-4	"	16.2	16.54	16.0	3	.40	255	14.29	2.5	.0005	1.26	.131	.02	58	6.0	.00001	.035	.0037	.0005	.126	.013
13-1	2750	10.0	9.95	10.2	[illegible]	11.9	44	8.0	0.35	1.24	54.3	.048	21.8	954	.85	.015	.67	.0006	.0062 .1103	.272 4.5	.00024 .004
13-2	"	13.2	13.55	12.7	305	5.05	29	11.94	0.35	.108	36.1	.034	1.9	634	.59	.0015	.492	.0005	.0005 .103	.12 2.01	.00016 .003
13-3	–	14.7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	2755	11.5	11.51	11.5	1,950	9.16	120	9.7	0.4	.493	46.7	.10	10.2	964	2.07	.007	.616	.0013	.0025 .411	.232 3.89	.0005 .008
14-2	"	13.2	13.98	12.6	198	5.24	60	11.85	0.8	.061	32.7	.062	1.26	675	1.27	.0007	.391	.0007	.0003 .0051	.164 2.73	.0003 .0051
14-3	"	14.7	15.31	14.3	9	.79	155	14.1	0.2	.003	5.25	.17	.06	108	3.5	.00004	.065	.0021	.00001 .00024	.026 .437	.00024 .014
14-4	–	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	2750	13.0	13.04	12.4	1870	5.57	429	11.5	0.35	.464	28.8	.364	10.9	672	8.5	.0059	.37	.0046	.0022 .029	.141 2.4	.0018 .020
15-2	"	13.2	13.38	12.5	1320	5.47	345	11.62	0.35	.345	28.9	.30	8.07	625	7.0	.004	.334	.0035	.0017 .029	.145 2.41	.0015 .025
15-3	"	14.7	14.92	14.1	75	2.77	315	13.1	0.8	.023	16.5	.307	.53	38.1	7.2	.00027	.196	.0027	.0011 .019	.082 1.37	.0015 .026
15-4	"	16.2	16.26	15.6	10	.11	534	14.44	2.0	.003	.42	.517	.06	14.5	12.07	.00003	.002	.0044	.0001 .0023	.0031 .0052	.0026 .043

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TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 182.5 / 188.5

0-200 ENGINE TEST DATA

DATE : Oct 13, 1972
REL. HUMIDITY: 60% / 60%
CARB. PRESSURE: 29.50 / 29.50 IN HG

RUN NO	TIME	RPM	TORQUE FT/LBS	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP °F				TEMPERTURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	BLAST. OF CAT	COOLING	EXH. GAS	
1-1	1620	900	21	13.38	900	10:1	0	17.5	76	–	–	–	7.5	10.19	240	205	320	285	135	510 530	125	450	33.0
1-2	"	"	"	"	"	"	90	"	"	5.7	80	.5	"	13.67	240	205	320	285	135	865 925	125	830	"
1-3	"	"	"	"	"	"	100	"	"	7.8	80	.8	"	15.05	240	205	320	285	135	1020 1070	130	1380	"
1-4	"	"	"	"	"	"	110	"	"	10.5	80	1.3	"	16.9	250	210	280	245	135	1210 1270	130	1490	"
2-1	1610	900	21	12.36	"	11.5:1	0	15.5	72	–	–	–	5.7	11.80	250	210	270	245	145	620 530	130	520	33.0
2-2	"	"	"	"	"	"	90	"	"	2.4	80	.1	"	13.66	250	210	270	245	145	760 620	130	650	"
2-3	"	"	"	"	"	"	100	"	"	4.3	80	.3	"	15.18	250	210	270	245	145	1220 1170	130	1110	"
2-4	"	"	"	"	"	"	110	"	"	6.2	80	.6	"	16.78	250	210	270	245	145	1215 1215	130	1090	"
3-1	1555	900	21	12.05	"	13:1	0	14.5	80	–	–	–	4.7	13.27	250	210	270	245	150	620 515	130	480	32.0
3-2	"	"	"	"	"	"	90	"	"	.5	80	.1	"	13.76	250	210	270	245	150	680 550	130	500	33.0
3-3	"	"	"	"	"	"	100	"	"	2.1	80	.1	"	15.26	250	210	270	245	150	910 940	130	800	"
3-4	"	"	"	"	"	"	110	"	"	3.7	80	.3	"	16.80	250	210	270	245	145	1080 1050	130	910	"
4-1	850	1100	31	13.94	1100	10.0:1	0	22.6	76	–	–	–	9.75	10.12	270	220	280	250	140	605 620	130	580	34.0
4-2	"	"	"	"	"	"	90	"	"	6.5	75	.5	"	12.18	270	270	280	250	140	1270 1230	130	1290	"
4-3	"	"	"	"	"	"	100	"	"	9.8	75	1.3	"	14.97	270	270	280	250	140	1330 1310	130	1220	"

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 182.5 / 188.5

0-200 ENGINE EMISSION DATA

DATE: Oct 13, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	Co %	Nox PPM	CO_2 %	O_2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
1-1	900	10.0	10.19	10.0	15,850	12.76	6.5	6.52	2.1	.492	7.99	.0007	65.55	1066	.09	.136	2.21	.00018	.0984	1.60	.00014
1-2	"	13.2	13.67	13.5	3,190	6.61	6	10.86	2.7	.123	5.16	.0008	16.44	688	.11	.034	1.43	.00022	.0246	1.03	.00016
1-3	"	14.7	15.05	14.6	2,140	4.38	12	12.08	2.7	.104	4.30	.0019	13.87	573	.25	.029	1.19	.00052	.0208	.86	.00038
1-4	"	16.2	16.9	16.0	160	.11	34	14.82	2.2	.008	.11	.0057	1.09	15	.76	.002	.03	.0016	.0016	.022	.00104
2-1	900	11.5	11.8	11.8	5,750	9.36	38	9.24	2.0	.146	4.79	.0032	25.62	841	.56	.040	1.32	.0009	.0292	.96	.00065
2-2	"	13.2	13.66	13.0	4,130	7.63	18	10.26	2.5	.114	4.27	.0016	20.07	749	.29	.0316	1.18	.00045	.0228	.854	.0003
2-3	"	14.7	15.18	15.7	155	.99	15	13.98	2.5	.006	.73	.0018	1.00	128	.32	.0016	.20	.0005	.00012	.146	.00076
2-4	"	16.2	16.78	16.8	50	.11	29	14.43	3.3	.002	.08	.0038	.32	15	.66	.0005	.023	.00104	.00004	.016	.00076
3-1	900	13.0	13.29	13.3	3,505	6.08	39	11.10	2.2	.084	2.93	.0031	17.32	624	.66	.023	.81	.00086	.0168	.586	.00062
3-2	"	13.2	13.76	13.7	2,635	5.74	40	11.36	2.5	.065	2.85	.0033	13.77	606	.70	.018	.79	.00091	.013	.57	.00066
3-3	"	14.7	15.26	15.1	670	1.75	12	13.55	2.0	.020	1.05	.0012	4.21	223	.25	.0055	.29	.00033	.004	.21	.00024
3-4	"	16.2	16.8	16.0	230	.22	30	14.36	2.2	.007	.14	.0031	1.52	29	.66	.002	.038	.00086	.0014	.028	.0006
4-1	1100	10.0	10.12	10.5	7,990	11.40	17	7.99	1.9	.291	8.37	.002	29.8	858	.20	.045	1.28	.0003	.0194	.558	.00013
4-2		13.2	13.18	13.3	1,230	7.43	9	10.65	1.25	.056	8.01	.0016	6.72	821	.17	.010	1.23	.00025	.0044	.534	.0001
4-3		14.7	14.97	14.7	75	1.30	14	13.73	1.1	.005	1.68	.0030	.47	173	.31	.00075	.26	.00047	.00033	.112	.0002

TEST CONDITION: CATALYTIC CONVERTER
IGNITION TIMING: 23° BTDC
ENGINE HRS: 182.5 / 188.5

0-200 ENGINE TEST DATA

DATE: Oct 13, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50

RUN No.	TIME	RPM	TORQUE FT/lbs	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP °F				TEMPERATURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CONV.	COWLING	EXH. GAS	
4-4	950	1100	31	13.94	1100	10:1	110	22.6	76	13.1	80	2.1	9.75	16.93	270	220	280	250	140	1430 1320	130	1400	34.0
5-1	330	1102	31	12.68	1100	11.5:1	0	20.1	76	–	–	–	7.55	11.62	270	230	285	255	135	610	130	520	34.0
5-2	"	"	"	"	"	"	90	"	"	3.0	75	.2	"	13.41	270	230	285	255	135	1045 965	130	870	"
5-3	"	"	"	"	"	"	100	"	"	5.2	75	.5	"	14.78	270	230	270	255	135	1225 1190	130	1150	"
5-4	"	"	"	"	"	"	110	"	"	7.8	75	.7	"	16.42	270	230	270	255	135	1225 1190	130	1185	"
6-1	240	1100	31	12.75	1100	13:1	0	19.9	76	–	–	–	6.5	13.23	280	235	290	270	140	700 660	135	620	34.0
6-2	"	"	"	"	"	"	90	"	"	.5	75	.1	"	13.71	280	235	290	270	140	740 710	135	640	"
6-3	"	"	"	"	"	"	100	"	"	2.6	75	.2	"	15.17	280	235	290	270	140	990 980	135	870	"
6-4	"	"	"	"	"	"	110	"	"	4.8	75	.4	"	16.73	280	235	290	270	140	1115 1070	130	1000	"
7-1	930	1702	73	18.19	1700	10:1	0	49.4	82	–	–	.45	21.1	10.02	365	300	380	340	160	870 555	170	870	35.0
7-2	"	"	"	"	"	"	90	"	"	15.0	105	1.3	"	13.38	365	300	380	340	160	1290 1420	170	1490	"
7-3	"	"	"	"	"	"	100	"	"	21.0	115	2.5	"	15.07	365	300	380	340	160	1650 1560	165	1680	"
7-4	"	"	"	"	"	"	110	"	"	26.5	125	3.8	"	16.87	365	300	380	340	160	1680 1550	165	1700	"
8-1	920	1702	73	17.80	"	11.5:1	0	47.0	80	–	–	.5	17.7	11.41	385	320	405	370	165	910 890	170	910	35.0
8-2	"	"	"	"	"	"	90	"	"	9.0	95	.8	"	13.08	380	310	395	370	165	1300 1270	170	1320	"

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 182.5 / 188.5

0-200 ENGINE EMISSION DATA

DATE: Oct 13, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	Co %	Nox PPM	CO2 %	O2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox
4-4	1100	16.2	16.93	16.5	15	.11	27	14.44	2.9	.001	.14	.0061	.11	15	.61	.00016	.022	.00093	.00007	.0093	.00041
5-1	1102	11.5	11.62	11.7	3510	10.42	37	7.93	2.2	.128	7.68	.0044	16.96	1017	.58	.0197	1.18	.00068	.0025	.512	.00029
5-2	"	13.2	13.41	13.8	390	3.44	8	12.73	1.5	.0163	2.92	.0011	2.16	387	.15	.0025	.449	.00018	.0011	.195	.00007
5-3	"	14.7	14.78	15.2	95	.41	24	14.28	1.35	.0041	.40	.0037	.59	53	.49	.00068	.061	.00057	.0003	.0267	.00025
5-4	"	16.2	16.42	16.4	16	.11	45	14.44	3.0	.0008	.11	.0075	.11	14	.99	.00012	.017	.00115	.00005	.0073	.0005
6-1	1100	13.0	13.23	13.0	2,405	5.34	96	11.58	1.3	.0846	3.79	.0112	13.01	584	1.72	.013	.584	.00172	.0058	.253	.00075
6-2	"	13.2	13.71	13.4	1,835	4.39	60	12.11	1.2	.0678	3.22	.0074	10.44	505	1.14	.01245	.506	.00114	.0045	.219	.0005
6-3	"	14.7	15.17	14.3	225	1.70	50	13.61	1.9	.0136	1.40	.0067	2.09	215	1.03	.0021	.215	.00103	.0009	.0933	.00045
6-4	"	16.2	16.73	17.0	80	.11	64	14.43	3.5	.0035	.09	.0092	.54	15	1.41	.00054	.015	.00132	.00023	.006	.00061
7-1	1703	10.0	10.02	10.2	6,815	12.55	21	7.53	1.1	.330	20.46	.0055	26.06	970	.26	.0232	.864	.00023	.0046	.1705	.00005
7-2	"	13.2	13.38	13.3	335	6.19	11	11.36	.45	.0416	15.53	.0044	1.97	736	.21	.00176	.656	.00019	.00035	.1294	.00004
7-3	"	14.7	15.07	14.7	10	.40	30	14.29	.6	.0013	1.13	.0137	.06	53	.65	.00005	.048	.00058	.00001	.0094	.00011
7-4	"	16.2	16.87	16.3	3	.11	33	14.44	2.6	.0005	.31	.0158	.02	15	.75	.00002	.013	.00067	–	.0026	.00013
8-1	1702	11.5	11.44	11.1	3,610	10.47	60	8.90	1.1	.317	18.55	.0175	17.90	1048	.99	.0134	.784	.00074	.00264	.1546	.00015
8-2	"	13.2	13.08	12.4	530	6.44	[illegible]	11.22	.7	.0553	13.59	.01	3.13	768	.62	.0023	.574	[illegible]	.00046	[illegible]	[illegible]

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 182.5 / 188.5

0-200 ENGINE TEST DATA

DATE : Oct 13, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN. HG

TEST NO.	TIME	RPM	TORQUE FT/LBS	MAP IN HG	NOM. TEST COND. RPM	A/F	% S.A.	INDUCTION AIR FLOW CFM	TEMP °F	SECONDARY AIR FLOW CFM	TEMP °F	PRESS. PSI	FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP °F #1	#2	#3	#4	TEMPERATURE °F OIL	REACT. OR CONV.	COWLING	EXH. GAS	OIL PRESS PSI
8-3	920	1702	73	17.80	1700	11.5:1	100	47.0	80	17.0	105	1.1	17.7	14.16	380	310	395	370	165	1440 1395	170	1470	35.0
8-4	"	"	"	"	"	"	110	"	"	24.0	115	2.0	"	16.13	380	310	395	370	165	1500 1410	170	1510	"
9-1	910	1700	73	17.91	"	13:1	0	46.7	80	-	-	.5	15.6	12.90	385	320	410	385	140	940 920	170	930	36.0
9-2	"	"	"	"	"	"	90	"	"	2.2	80	.5	"	13.54	385	320	410	385	150	1060 1020	170	1040	35.5
9-3	"	"	"	"	"	"	100	"	"	8.5	90	.7	"	15.39	385	320	410	385	150	1320 1290	170	1335	35.0
9-4	"	"	"	"	"	"	110	"	"	11.5	100	1.1	"	16.36	390	320	420	385	155	1420 1345	170	1420	"
10-1	1050	1955	96	22.44	1950	10:1	0	74.2	85	-	-	.7	31.3	10.04	400	340	420	405	185	990 965	175	1000	34.5
10-2	"	"	"	"	"	"	90	"	"	20.0	125	3.0	"	13.34	390	340	420	390	185	1640 1550	180	1640	"
10-3	"	"	"	"	"	"	100	"	"	30.0	145	3.8	"	15.22	390	340	420	390	185	1840 1705	180	1840	"
10-4	-	-	-	-	"	"	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11-1	1040	1955	96	20.95	"	11.5:1	0	66.9	85	-	-	.6	25.1	11.29	420	360	450	420	175	1030 985	180	1030	35.0
11-2	"	"	"	"	"	"	90	"	"	12.0	105	1.3	"	13.52	420	360	450	420	175	1310 1270	180	1345	"
11-3	"	"	"	"	"	"	100	"	"	20.0	115	2.1	"	15.2	420	360	450	420	175	1520 1450	180	1570	"
11-4	"	"	"	"	"	"	110	"	"	26.0	125	3.5	"	16.8	420	360	450	420	180	1615 1550	185	1670	34.0
12-1	1030	1950	96	20.55	"	13:1	0	63.7	80	-	-	.6	21.3	12.93	425	350	460	425	145	1050 1025	180	1050	37.0

TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 23° BTDC
ENGINE PRS: 182.5 / 182.5

0-200 ENGINE EMISSION DATA

DATE: Oct 13, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB/HR			LB/1000 lb FUEL			LB/BHP HR			LB/MODE		
		NOM.	DIR	C.B	THC PPM-C	Co %	NOx PPM	CO_2 %	O_2 %	THC	Co	Nox	THC	Co	Nox	THC	Co	Nox	THC	Co	No.x
8-3	1702	14.7	14.16	14.1	25	1.27	28	13.85	.55	.003	3.23	.0117	.15	165	.60	.00012	.136	.00049	.00003	.0269	.0001
8-4	"	16.2	16.13	16.0	6	.11	61	14.49	2.1	.0008	.28	.026	.04	14	1.33	.00003	.012	.00110	–	.0023	.00022
9-1	1700	13.0	12.9	12.6	2,395	6.32	173	11.09	1.2	.209	11.12	.0515	13.36	713	3.30	.0088	.470	.00218	.0018	.0927	.00043
9-2	"	13.2	13.54	12.7	1,370	6.03	169	11.34	1.1	.1243	11.03	.0507	7.97	707	3.25	.00526	.467	.00215	.0011	.0919	.00042
9-3	"	14.7	15.39	14.6	135	.60	48	14.18	.5	.0142	1.27	.0166	.91	82	1.07	.0006	.054	.0007	.00012	.0106	.00014
9-4	"	16.2	16.26	15.2	6	.30	144	14.34	1.15	.0007	.67	.0524	.04	43	3.36	.00003	.028	.0022	–	.0056	.00044
10-1	1955	10.0	10.04	10.2	4,840	12.49	24	7.76	.8	.572	20.23	.0095	18.28	953	.30	.0160	.235	.00027	.0572	2.93	.00095
10-2	"	13.2	13.34	12.0	177	4.33	7.5	12.31	.45	.0336	16.58	.0047	1.07	530	.15	.00094	.464	.00013	.0034	1.66	.0005
10-3	"	14.7	15.22	14.6	45	1.19	29	13.89	1.0	.0094	5.06	.0205	.30	162	.65	.00026	.141	.00057	.001	.51	.0021
10-4	"	16.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11-1	1955	11.5	11.29	11.0	3,100	10.86	65	8.75	1.0	.378	26.76	.0265	15.07	1066	1.06	.0106	.749	.00074	.038	2.68	.0027
11-2	"	13.2	13.52	12.7	275	5.44	43	11.74	.55	.041	16.50	.0216	1.63	653	.86	.00114	.462	.0006	.0041	1.65	.0022
11-3	"	14.7	15.2	14.5	15	.99	57	13.99	.6	.0025	3.37	.0318	.10	134	1.27	.00007	.094	.0009	.0003	.34	.0032
11-4	"	16.2	16.8	15.9	3	.21	74	14.39	2.2	.0005	.73	.0431	.02	29	1.72	.00002	.026	.0012	.00005	.073	.0043
12-1	1950	13.0	12.93	12.5	1985	6.21	233	11.19	.9	.241	15.21	.094	11.30	714	4.41	.0062	.427	.00262	.024	1.57	.0091

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TEST CONDITION: CATALYTIC CONVERTOR
IGNITION TIMING: 23° BTDC
ENGINE HRS: 182.5 / 183.5

O-200 ENGINE TEST DATA

DATE: Oct 13, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 IN HG

RUN NO	TIME	RPM	TORQUE FT/LBS	MAP IN HG	NOM. TEST COND.			INDUCTION AIR		SECONDARY AIR			FUEL FLOW PPH	CALC. A/F	CYLINDER HEAD TEMP. °F				TEMPERATURE °F				OIL PRESS PSI
					RPM	A/F	% S.A.	FLOW CFM	TEMP °F	FLOW CFM	TEMP °F	PRESS. PSI			#1	#2	#3	#4	OIL	REACT. OR CONV.	COWLING	EXH. GAS	
12-2	1030	1950	96	20.55	1950	13:1	90	63.9	80	4.0	85	1.0	21.3	13.80	425	350	460	425	155	1220 1180	180	1235	36.5
12-3	"	"	"	"	"	"	100	"	"	10.0	95	1.5	"	15.19	425	350	460	425	160	1370 1320	180	1410	36.0
12-4	"	"	"	"	"	"	110	"	"	15.0	110	1.8	"	16.38	425	350	460	425	165	1470 1415	180	1510	35.5
13-1	1700	2750	130	28.34	2750	10:1	0	142.7	100	–	–	2.2	58.1	9.86	560	455	495	430	235	1205 1110	220	–	33.0
13-2	–	–	–	–	"	"	90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-1	1645	2750	145	28.34	"	11.5:1	0	141.0	95	–	–	2.2	50.2	11.48	570	465	575	520	220	1200 1160	220	–	34.5
14-2	"	"	140	"	"	"	90	"	"	24.0	145	3.8	"	13.98	570	465	575	510	220	1470 1405	220	–	34.0
14-3	–	–	–	–	"	"	100	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14-4	–	–	–	–	"	"	110	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15-1	1620	2745	150	28.34	"	13:1	0	139.0	90	–	–	2.1	45.1	12.83	550	455	570	540	160	1205 1205	210	1205	40.0
15-2	"	"	150	"	"	"	90	"	"	5.0	90	2.8	"	13.38	560	460	585	535	175	1310 1210	210	1310	39.0
15-3	"	"	145	"	"	"	100	"	"	21.0	120	3.8	"	15.30	570	465	605	540	190	1515 1470	210	1470	37.5
15-4	"	"	140	"	"	"	110	"	"	28.0	160	3.8	"	16.12	570	465	605	540	205	1700 1540	220	1540	36.0

TEST CONDITION: CATALYTIC CONVERTER
IGNITION TIMING: 23° BTDC
ENGINE HRS: 182.5 / 188.5

0-200 ENGINE EMISSION DATA

DATE: Oct 13, 1972
REL. HUMIDITY: 60% / 60%
BARO. PRESSURE: 29.50 / 29.50 in HG

RUN Nº	RPM	EXH. GAS A/F RATIO			CORRECTED CONCENTRATION					LB / HR			LB / 1000 lb FUEL			LB / BHP HR			LB / MODE		
		NOM.	DIR	C.B	THC PPM-C	CO %	NOx PPM	CO₂ %	O₂ %	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx	THC	CO	NOx
12-2	1950	13.2	13.90	13.0	390	4.70	110	12.10	.6	.051	12.41	.028	2.39	583	2.24	.00143	.348	.00134	.005	1.24	.0042
12-3	"	14.7	15.19	13.8	52	2.38	56	13.30	.4	.0077	7.01	.027	.36	329	1.26	.00021	.197	.00076	.0008	.701	.0027
12-4	"	16.2	16.38	15.5	6	.45	171	14.27	1.8	.0009	1.37	.086	.04	64	4.04	.00003	.039	.00241	.0001	.137	.0086
13-1	2750	10.0	9.86	10.0	5,320	12.28	44	7.82	.35	1.20	55.98	.0331	20.56	964	.57	.0170	.793	.00047	.006 .10	.28 4.67	.00017 .0028
13-2	"	13.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-3	"	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-1	2750	11.5	11.48	11.0	2,830	9.77	69	9.32	.35	.67	46.45	.0538	13.28	925	1.07	.0088	.612	.00071	.0034 .056	.232 3.87	.00027 .0045
14-2	"	12.2	13.98	12.9	390	7.38	35	10.76	.3	.122	46.54	.0365	2.42	927	.73	.00165	.630	.0005	.00061 .0102	.233 3.88	.00015 [illegible]
14-3	"	14.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14-4	"	16.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15-1	2745	13.0	12.83	12.6	1,815	7.76	347	10.43	.35	.47	40.37	.296	10.36	895	6.56	.0060	.521	.00382	.00235 .0392	.202 3.36	.0015 .0247
15-2	"	13.2	13.38	12.8	495	6.38	235	11.25	.3	.133	34.56	.209	2.96	766	4.64	.0017	.440	.00266	.00067 .0111	.173 2.88	.00105 .0174
15-3	"	14.7	15.30	14.1	90	2.99	129	12.99	.9	.027	18.70	.134	.60	419	2.41	.00036	.249	.00176	.00014 .00235	.0945 1.575	.00017 .0112
15-4	"	16.2	16.12	15.7	30	.20	272	14.39	2.2	.0095	1.27	.280	.21	28	6.20	.00013	.017	.00381	[illegible] [illegible]	.0063 .106	.0018 .0222

APPENDIX C

DATA AND COMPUTED VALUES FOR LYCOMING IO-540 ENGINE

C1 - Engine Variables and PCV Effects Evaluation

C2 - Ignition Timing Recheck Runs

APPENDIX C1

ENGINE VARIABLES AND PCV EFFECTS EVALUATION

IO540 ENGINE TEST DATA

TEST CONDITION Baseline + PCV

IGNITION TIMING 25 °BTDC

ENGINE HOURS 197.2/203.1

FUEL 100/130 LEADED

DATE 12-21-72

REL. HUMIDITY 65 %/65 %

BARO. PRESSURE 29.20 IN HG.

RUN №	TIME	NOMINAL		OBSERVED		M.A.P	INDUCTION AIR		CRANK CASE	EXH. BACK. PRESS. PSI	FUEL FLOW PPH	OBS. F/A	OIL	
		RPM / A/F	S.A. %	RPM	TORQUE FT. LBS	MM HG	FLOW CFM	TEMP. °F	FLOW CFM / TEMP °F				TEMP °F	PRESS PSI
1	0905	1900 / 10:1	-	1898	249	502	160.5	85	– / –	0.1	67.5	.0927	220	57.0
1-P	0910	/ 10:1	-	1900	253	512	164	85	1.32 / 150	0.1	69.5	.0933	225	57.0
2	0920	/ 11.5:1	-	1903	247	485	153.4	85	– / –	0.1	55.9	.0839	220	57.0
2-P	0925	/ 11.5:1	-	1902	251	492	154.5	85	1.25 / 150	0.1	56.1	.0801	230	57.0
3	0950	/ 13:1	-	1892	255	501	157.3	90	– / –	0.1	50.0	.0700	240	53.0
3-P	0955	/ 13:1	-	1899	253	506	159.1	90	1.25 / 150	0.1	50.5	.0700	245	51.0
4	1015	1000 / 10:1	-	1007	75	334	43.5	73	– / –	0	19.0	.0971	245	59.0
4-P	1020	/ 10:1	-	1009	75	340	43.1	73	.08 / 150	0	19.0	.0968	245	59.0
5	1025	/ 11.5:1	-	1009	78	326	41.6	73	– / –	0	15.9	.0848	135	59.0
5-P	1030	/ 11.5:1	-	1006	75	329	41.2	73	.08 / 150	0	15.8	.0849	135	59.0
6	1040	/ 13:1	-	1004	75	310	38.6	72	– / –	0	12.7	.0740	140	58.0
6-P	1045	/ 13:1	-	1005	80	311	39.0	73	.08 / 150	0	12.8	.0730	150	58.0

TEST CONDITION BASELINE + PCV

IGNITION TIMING 25 °BTDC

ENGINE HOURS 197.7 / 203.1

DATE 12-21-72

RUN No.	CYLINDER HEAD/EXHAUST PORT TEMP. °F						EXH. GAS TEMP. °F	EMISSIONS				
	#1	#2	#3	#4	#5	#6		THC PPM	CO %	CO2 %	O2 %	NOX PPM
1	315/1210	305/1185	290/1130	305/*	300/1210	315/*	1040	1100	13.4	6.3	1.5	40
1-P	320/1200	315/1185	300/1120	315/*	305/1110	320/*	1030	1050	13.4	6.0	1.5	39
2	320/1290	305/1260	290/1200	315/*	300/1280	330/*	1080	860	9.6	8.7	1.4	135
2-P	340/1285	320/1260	320/1200	335/*	325/1300	340/*	1080	875	9.6	8.7	1.3	143
3	370/1400	355/1330	310/1265	355/*	340/1345	365/*	1140	670	6.1	10.9	1.1	535
3-P	370/1380	355/1330	340/1270	355/*	340/1340	370/*	1140	670	6.3	10.9	1.0	500
4	220/1055	205/1110	205/920	215/*	220/1065	225/*	660	4900	11.8	6.8	1.08	1.9
4-P	220/1060	205/1140	205/925	220/*	215/1090	225/*	660	5400	11.9	6.8	1.15	1.4
5	225/1030	220/1060	215/910	215/*	230/1040	235/*	635	2000	9.4	8.8	.92	43
5-P	230/1040	220/1070	220/910	230/*	225/1050	240/*	635	1970	9.3	8.9	.90	44
6	225/1050	220/1090	220/975	230/*	230/1125	240/*	655	1300	4.8	11.9	.99	85
6-P	225/1090	220/1105	220/965	220/*	245/1115	245/*	655	1270	4.65	12.3	.85	85

IO540 ENGINE TEST DATA

TEST CONDITION Baseline + PCV
IGNITION TIMING 25 °BTDC
ENGINE HOURS 197.7 / 203.1
FUEL 100/130 LEADED

DATE 12-21-72
REL. HUMIDITY 65 % / 65 %
BARO. PRESSURE 29.2 IN HG.

RUN Nº	TIME	NOMINAL		OBSERVED		M.A.P	INDUCTION AIR		CRANK CASE	EXH. BACK PRESS. PSI	FUEL FLOW PPH	OBS. F/A	OIL	
		RPM / A/F	S.A. %	RPM	TORQUE FT. LBS	MM HG	FLOW CFM	TEMP. °F	FLOW CFM / TEMP °F				TEMP °F	PRESS PSI
7	1130	2400 / 10:1	-	2398	375	645	272	75	- / -	0.8	120.0	.0965	240	58.0
7-P	1135	10:1	-	2410	380	657	283	76	2.75 / 150	0.8	125.0	.0967	250	55.0
8	1140	11.5:1	-	2395	385	654	278	76	- / -	0.8	105.0	.0833	300	42.0
8-P	1145	11.5:1	-	2402	390	659	278	76	2.83 / 150	0.8	107.0	.0845	305	42.0
9	1147	13:1	-	2403	385	646	272	77	- / -	0.7	90.0	.0729	305	40.0
9-P	1150	13:1	-	2410	390	658	276	77	2.67 / 150	0.7	90.5	.0728	310	38.0
10	1155	1900 / 11.5:1	-	1902	255	508	157	77	- / -	0.1	59.0	.0824	250	36.0
11	1545	2700 / 10:1	-	2707	400	676	340	80	- / -	1.2	144.0	.0936	260	56.0
11-P	1550	10:1	-	2705	390	676	334	80	3.75 / 150	1.2	140.0	.0930	280	54.0
12	1552	11.5:1	-	2693	410	676	333	82	- / -	1.2	125.0	.0825	300	42.0
12-P	1555	11.5:1	-	2710	400	676	330	82	3.5 / 150	1.2	127.0	.0837	305	42.0
13	1600	13:1	-	2701	410	676	330	82	- / -	1.2	108.0	.0725	330	40.0
13-P	1605	13:1	-	2695	395	676	327	82	3.33 / 150	1.2	109.0	.0737	340	37.0

TEST CONDITION BASELINE + PCV

IGNITION TIMING 25 °BTDC

ENGINE HOURS 197.7 / 203.1

DATE 12-21-72

RUN Nº	CYLINDER HEAD/EXHAUST PORT TEMP. °F						EXH. GAS TEMP. °F	EMISSIONS				
	#1	#2	#3	#4	#5	#6		THC PPM	CO %	CO₂ %	O₂ %	NOX PPM
7	385/1225	375/1235	355/1200	355/*	370/1285	395/*	1170	1000	13.1	6.4	.63	43
7-P	385/1225	375/1230	355/1185	355/*	385/1275	*/*	1165	1000	13.5	6.8	.62	35
8	440/1305	440/1300	400/1270	395/*	425/1380	*/*	1250	625	9.5	8.6	.61	167
8-P	440/1310	430/1300	400/1270	385/*	425/1380	*/*	1240	630	9.6	8.6	.60	157
9	470/1430	465/1390	435/1360	425/*	455/1495	*/*	1320	470	6.1	10.5	.61	595
9-P	475/1440	465/1390	440/1380	430/*	465/1500	*/*	1330	460	5.8	11.2	.61	510
10	360/1330	340/1235	325/1185	305/*	335/1280	*/*	1075	920	9.6	8.5	.71	163
11	425/1270	420/*	370/1240	365/*	395/1330	*/*	1200	850	13.4	6.1	.44	40
11-P	425/1275	425/*	380/1260	350/*	400/1340	*/*	1205	860	13.7	5.8	.48	16
12	460/1260	470/*	430/1320	415/*	430/1420	485/*	1270	590	10.3	7.8	.50	112
12-P	470/1260	470/*	430/1320	440/*	455/1415	490/*	1270	625	11.3	7.4	.50	73
13	515/*	505/*	470/1425	440/*	500/1505	530/*	1360	410	6.7	10.1	.49	510
13-P	515/*	505/*	470/1415	415/*	500/1420	530/*	1360	435	7.4	9.7	.49	390

IO540 ENGINE TEST DATA

TEST CONDITION Baseline + PCV
IGNITION TIMING 25 °BTDC
ENGINE HOURS 203.8/204.4
FUEL 100/130 LEADED

DATE 12-22-72
REL. HUMIDITY 60 %/60 %
BARO. PRESSURE 29.20 IN HG.

RUN NO	TIME	NOMINAL		OBSERVED		M.A.P	INDUCTION AIR		CRANK CASE	EXH.	FUEL	OBS.	OIL	
		RPM / A/F	S.A. %	RPM	TORQUE FT. LBS	MM HG	FLOW CFM	TEMP °F	FLOW CFM / TEMP °F	BACK. PRESS. PSI	FLOW PPH	F/A	TEMP °F	PRESS PSI
15	0840	1900 15.5:1	-	1903	255	498	153.0	80	- -	0.1	56.8	.0821	225	56.0
16	0845	2700 10:1	-	2696	405	675	336.0	80	- -	1.2	143.0	.0936	260	56.0
[illegible]	0855	1000 10:1	-	1002	80	334	43.4	78	- -	0	18.5	.0947	300	48.0

TEST CONDITION _BASELINE + PCV

IGNITION TIMING _25_ °BTDC

ENGINE HOURS 203.8 / 204.4

DATE 12-22-72

RUN Nº	CYLINDER HEAD/EXHAUST PORT TEMP. °F						EXH. GAS TEMP. °F	EMISSIONS				
	#1	#2	#3	#4	#5	#6		THC PPM	CO %	CO_2 %	O_2 %	NOX PPM
15	340 / 1235	340 / *	325 / 1235	340 / *	310 / 1300	365 / *	1090	870	9.0	8.4	.80	158
16	410 / 840	415 / *	365 / 1240	400 / *	395 / 1325	435 / *	1215	900	13.1	5.8	.64	46
17	230 / 1015	225 / *	210 / 930	240 / *	230 / 1040	240 / *	630	5100	10.5	6.7	1.3	30

IO540 ENGINE TEST DATA

TEST CONDITION BASELINE + PCV

IGNITION TIMING 20 °BTDC

ENGINE HOURS 201.1/ 205.5

FUEL 100/130 LEADED

DATE 12-22-72

REL. HUMIDITY 60 %/ 60%

BARO. PRESSURE 29.2 IN HG.

RUN No.	TIME	NOMINAL		OBSERVED		M.A.P	INDUCTION AIR		CRANK CASE	EXH.	FUEL	OBS.	OIL	
		RPM/A/F	S.A. %	RPM	TORQUE FT. LBS	MM HG	FLOW CFM	TEMP °F	FLOW CFM/TEMP °F	BACK. PRESS. PSI	FLOW PPH	F/A	TEMP °F	PRESS PSI
18	0925	1900/10:1	-	1896	250	526	166.5	78	-/-	0.2	71.5	.0950	200	58.0
19	0930	/11.5:1	-	1900	255	514	157.7	78	-/-	0.2	59.4	.0824	230	54.0
19-P	0935	/11.5:1	-	1901	260	526	159.3	78	1.25/150	0.2	60.0	.0830	230	54.0
20	0937	/13:1	-	1902	255	506	154.2	78	-/-	0.2	50.8	.0724	230	52.0
21	0940	1000/10:1	-	1004	75	344	42.5	78	-/-	0	18.6	.0951	180	48.0
22	0945	/11.5:1	-	1004	75	305	39.8	76	-/-	0	14.8	.0836	170	54.0
22-P	0950	/11.5:1	-	1004	80	326	40.7	76	.08/150	0	15.2	.0828	160	54.0
23	0955	/13:1	-	1004	80	330	42.1	73	-/-	0	13.9	.0746	160	56.0
24	1000	2400/10:1	-	2395	375	654	293.0	80	-/-	0.9	126.5	.0950	200	64.0
25	1003	/11.5:1	-	2402	385	655	287.0	80	-/-	0.9	108.0	.0825	240	56.0
25-P	1005	/11.5:1	-	2406	380	670	290.0	82	2.67/150	0.9	108.0	.0820	250	48.0
26	1010	/13:1	-	2407	385	654	281.0	80	-/-	0.9	93.0	.0730	290	44.0

TEST CONDITION BASELINE + PCV

DATE 12-22-72

IGNITION TIMING 20 °BTDC

ENGINE HOURS 204.4/205.5

RUN NO.	CYLINDER HEAD/EXHAUST PORT TEMP. °F						EXH. GAS TEMP. °F	EMISSIONS				
	#1	#2	#3	#4	#5	#6		THC PPM	CO %	CO2 %	O2 %	NOX PPM
18	320/1190	325/*	300/1185	320/*	315/1265	340/*	1080	1200	12.3	6.1	.7	49
19	355/1210	340/*	325/1280	350/*	335/1350	355/*	1140	790	8.7	8.6	.68	132
19-P	350/1250	340/*	335/1280	355/*	340/1350	*/*	1140	790	8.8	8.6	.68	132
20	370/1390	365/*	335/1260	355/*	355/1410	380/*	1190	615	5.3	11.0	.7	500
21	240/1110	225/*	220/980	235/*	230/1090	245/*	655	5400	10.7	6.8	1.0	26
22	230/1080	225/*	220/980	235/*	230/1110	240/*	645	2300	8.0	9.0	.9	55
22-P	230/1080	225/*	220/980	235/*	225/1100	240/*	640	2300	8.0	9.0	.8	55
23	235/1125	225/*	240/990	225/*	235/1170	240/*	685	1400	5.7	10.7	.5	77
24	355/1150	355/*	320/1240	315/*	350/*	385/*	1200	1033	13.1	5.9	.5	37
25	400/*	415/*	370/1320	410/*	400/*	445/*	1285	675	9.6	8.1	.51	125
25-P	415/*	415/*	370/1300	415/*	400/*	445/*	1270	655	10.0	8.0	.52	103
26	415/*	425/*	370/1300	415/*	410/*	*/*	1115	435	6.3	10.6	.55	345

IO540 ENGINE TEST DATA

TEST CONDITION BASELINE + PCV
IGNITION TIMING 15 °BTDC
ENGINE HOURS 205.5/ 206.7
FUEL 100/130 LEADED

DATE 12-22-72
REL. HUMIDITY 60 %/ 60 %
BARO. PRESSURE 29.2 IN HG.

RUN NO	TIME	NOMINAL		OBSERVED		M.A.P	INDUCTION AIR		CRANK CASE	EXH.	FUEL	OBS.	OIL	
		RPM / A/F	S.A. %	RPM	TORQUE FT. LBS	MM HG	FLOW CFM	TEMP °F	FLOW CFM / TEMP °F	BACK. PRESS. PSI	FLOW PPH	F/A	TEMP °F	PRESS PSI
27	1050	1900 / 10:1	-	1909	255	574	187.0	78	- / -	0.2	81.0	.0949	210	56.0
28	1055	/ 11.5:1	-	1901	250	531	166.0	80	- / -	0.2	61.6	.0820	225	52.0
28-P	1057	/ 11.5:1	-	1905	250	543	167.5	80	1.25 / 150	0.2	62.0	.0818	[illegible]	52.0
29	1059	/ 13:1	-	1895	250	524	160.5	80	- / -	0.2	51.8	.0720	[illegible]	50.0
30	1105	1000 / 10:1	-	1005	75	361	46.7	75	- / -	0	20.1	[illegible]	[illegible]	46.0
31	1112	/ 11.5:1	-	1008	75	342	44.0	75	- / -	0	16.7	.0838	180	52.0
31-P	1115	/ 13:1	-	1007	80	350	44.3	75	.08 / 150	0	16.6	.0836	[illegible]	54.0
32	1120	/ 13:1	-	1000	80	341	43.8	73	- / -	0	14.3	.0728	155	56.0
33	1128	2400 / 10:1	-	2399	370	676	309.3	80	- / -	0.9	133.0	.0951	220	60.0
34	1130	/ 11.5:1	-	2402	390	676	302.4	80	- / -	0.9	113.0	.0824	250	56.0
34-P	1132	/ 11.5:1	-	2406	390	676	295.0	81	2.83 / 150	0.9	109.0	.0816	260	56.0
35	1135	/ 13:1	-	2410	395	676	299.0	83	- / -	0.9	97.5	.0710	290	48.0

TEST CONDITION BASELINE + PCV

IGNITION TIMING 15 °BTDC

ENGINE HOURS 205.5/ 206.2

DATE 12-22-72

RUN Nº	CYLINDER HEAD/EXHAUST PORT TEMP. °F						EXH. GAS TEMP. °F	EMISSIONS				
	#1	#2	#3	#4	#5	#6		THC PPM	CO %	CO2 %	O2 %	NOX PPM
27	340/1160	330/*	305/1225	335/*	320/1310	415/*	1165	1210	13.1	6.2	.44	275
28	350/1300	325/*	325/1305	350/*	335/1390	350/*	1185	790	9.4	8.6	.51	105
28-P	355/1340	350/*	325/1300	340/*	340/1395	365/*	1180	780	9.2	8.6	.53	107
29	370/1460	365/*	340/1400	355/*	360/1480	380/*	1250	560	5.5	11.0	.6	400
30	245/1060	230/*	215/985	250/*	235/1120	215/*	1605	7500	10.8	6.6	1.3	28
31	230/1110	230/*	220/1030	240/*	230/1130	240/*	720	3700	9.0	8.2	.9	43
31-P	230/1080	230/*	205/1030	245/*	215/1150	235/*	700	2500	8.3	8.8	.99	53
32	240/1160	235/*	240/1065	240/*	230/1220	240/*	720	1270	5.4	10.9	.8	78
33	365/1300	360/*	330/1320	355/*	340/*	385/*	1280	1000	13.1	6.3	.51	34
34	400/1340	405/*	355/1370	385/*	385/*	415/*	1350	650	9.5	8.5	.49	115
34-P	400/1365	405/*	365/1365	405/*	395/*	435/*	1360	610	8.9	8.8	.49	135
35	440/1165	455/*	400/1465	440/*	425/*	475/*	1410	440	6.1	10.9	.49	410

COMPUTED VALUES

RUN NO.	RPM	AIR-FUEL RATIO			CORRECTED CONCENTRATIONS				
		NOM.	DIRECT	C.B.	THC PPM-C	CO%	NOx PPM	CO2%	O2%
1	1900	10.0	10.0	10.3	3551	14.42	53.8	6.78	1.61
1P	1900	10.0	9.9	10.2	3472	14.77	53.8	6.61	1.65
2	1900	11.5	11.5	11.7	2690	10.01	176.0	9.07	1.46
2P	1900	11.5	11.5	11.6	2736	10.01	186.4	9.07	1.36
3	1900	13.0	13.0	12.9	2037	6.18	777.3	11.05	1.12
3P	1900	13.0	13.0	12.8	2023	6.34	721.3	10.97	1.01
4	1000	10.0	10.0	9.9	14882	11.95	2.1	6.88	1.09
4P	1000	10.0	9.9	9.9	16173	11.88	1.0	6.79	1.15
5	1000	11.5	11.4	11.3	6104	9.56	44.8	8.95	.94
5P	1000	11.5	11.4	11.3	5984	9.44	45.7	9.03	.91
6	1000	13.5	13.3	13.2	3808	4.69	83.8	11.62	.97
6P	1000	13.5	13.3	13.2	3637	4.41	83.3	11.78	.81
7	2400	10.0	9.8	9.9	3248	14.18	61.5	6.93	.68
7P	2400	10.0	9.8	10.0	3107	13.98	38.5	7.04	.64
8	2400	11.5	11.4	11.3	1987	10.07	188.0	9.11	.65
8P	2400	11.0	11.2	11.3	1995	10.13	176.1	9.08	.63
9	2400	13.0	13.0	12.6	1477	6.39	674.2	11.00	.64
9P	2400	13.0	13.1	12.8	1390	5.84	751.8	11.29	.61
10	1900	11.5	11.5	11.3	2916	10.14	186.3	8.98	.75
11	2700	10.0	10.1	9.7	2802	14.73	49.8	6.70	.48
11P	2700	10.0	10.2	9.5	2867	15.23	20.2	6.45	.53
12	2700	11.5	11.3	10.9	1934	11.26	143.6	8.52	.55
12P	2700	11.0	11.0	10.5	2032	12.25	92.8	8.02	.54
13	2700	13.0	12.9	12.3	1300	7.08	632.4	10.68	.52
13P	2700	12.5	12.7	12.0	1383	7.85	485.1	10.28	.52
15	1900	11.5	11.5	11.4	2845	9.81	187.6	9.16	.87
16	2700	10.0	10.0	9.7	3069	14.89	56.9	6.59	.73
17	1000	10.0	10.1	11.0	1988	12.43	37.6	7.93	1.54
18	1900	10.0	10.0	9.9	4063	14.11	58.6	6.89	.79
19	1900	11.5	11.4	11.5	2578	9.46	152.0	9.36	.74
19P	1900	11.5	11.4	11.5	2568	9.54	151.5	9.32	.74
20	1900	13.0	13.0	12.9	1913	5.50	548.9	11.41	.73
21	1000	10.0	10.0	10.0	16877	11.15	28.7	7.08	1.04
22	1000	11.5	11.6	11.6	7230	8.38	59.2	9.43	.94
23	1000	13.0	13.2	12.5	4313	5.85	78.3	10.99	.51
24	2400	10.0	9.9	9.7	3484	14.73	45.3	6.63	.56
25	2400	11.5	11.3	11.1	2217	10.51	149.1	8.87	.56
25P	2400	11.5	11.4	11.0	2136	10.87	125.5	8.70	.57
26	2400	13.0	12.8	12.5	1410	6.51	515.5	10.95	.57
27	1900	10.0	9.9	9.7	3971	14.33	31.3	6.78	.48
28	1900	11.5	11.5	11.3	2530	9.82	122.1	9.18	.54
28P	1900	11.5	11.5	11.3	2498	9.82	124.4	9.18	.57
29	1900	13.0	13.2	12.8	1731	5.67	449.0	11.34	.62
30	1000	10.0	10.1	9.7	22651	10.87	28.6	6.64	1.31
31	1000	11.5	11.4	10.9	11531	9.35	45.4	8.52	.93
31P	1000	11.5	11.6	11.5	7853	8.69	56.4	9.22	1.04
32	1000	13.5	13.4	12.8	3897	5.54	79.2	11.19	.82
33	2400	10.0	9.9	9.8	3272	14.29	40.4	6.87	.56
34	2400	11.5	11.4	11.2	2080	10.14	133.6	9.07	.52
34P	2400	11.5	11.5	11.4	1954	9.51	158.7	9.40	.52
35	2400	13.0	12.9	12.6	1344	6.21	478.9	11.10	.50

COMPUTED VALUES

RUN NO.	LB/HR			LB/1000 LB FUEL		
	THC	CO	NOx	THC	CO	NOx
1	1.0136	83.12	.05095	15.0167	1231.398	.7548
1P	.9888	84.94	.05077	14.2270	1222.191	.7305
2	.7524	56.54	.16326	13.4597	1011.391	2.9207
2P	.7708	56.93	.17413	13.7398	1014.741	3.1040
3	.5839	35.79	.73874	11.6784	715.732	14.7747
3P	.5905	37.38	.69819	11.6932	740.131	13.8256
4	1.2747	20.66	.00059	67.0883	1087.536	.0310
4P	1.3920	20.65	.00029	73.2657	1086.837	.0153
5	.4945	15.65	.01203	31.1025	984.019	.7564
5P	.4816	15.33	.01219	30.4786	970.523	.7715
6	.2947	7.33	.02151	23.2068	576.798	1.6935
6P	.2891	7.07	.02195	22.5828	552.349	1.7150
7	1.6162	142.52	.10149	13.4682	1187.658	.8458
7P	1.6760	152.31	.06890	13.4079	1218.440	.5512
8	1.0223	104.60	.32084	9.7360	996.178	3.0556
8P	1.0318	105.84	.30202	9.6430	989.130	2.8226
9	.7404	64.69	1.12054	8.2269	718.748	12.4505
9P	.7345	62.34	1.31712	8.1162	688.866	14.5538
10	.8469	59.49	.17937	14.3537	1008.229	3.0402
11	1.6877	179.10	.09955	11.7202	1243.744	.6913
11P	1.6770	179.83	.03911	11.9787	1284.520	.2793
12	1.1337	133.23	.27913	9.0699	1065.853	2.2330
12P	1.1920	145.07	.18057	9.3859	1142.318	1.4218
13	.7709	84.81	1.24375	7.1383	785.232	11.5162
13P	.8122	93.01	.94442	7.4514	853.280	8.6644
15	.7724	53.79	.16890	13.5989	946.975	2.9736
16	1.7661	173.05	.10869	12.3506	1210.120	.7600
17	.1429	18.04	.00896	7.7242	974.917	.4843
18	1.1749	82.39	.05615	16.4325	1152.243	.7854
19	.7283	53.99	.14243	12.2606	908.893	2.3978
19P	.7357	55.16	.14388	12.2611	919.378	2.3979
20	.5473	31.75	.52084	10.7742	625.024	10.2528
21	1.3812	18.42	.00778	74.2589	990.488	.4185
22	.5380	12.60	.01460	36.3486	851.060	.9865
23	.3453	9.46	.02078	24.8434	680.875	1.4952
24	1.7681	150.94	.07625	13.9774	1193.182	.6028
25	1.1252	107.73	.25089	10.4189	997.472	2.3231
25P	1.0955	112.59	.21354	10.1437	1042.472	1.9772
26	.7295	67.99	.88433	7.8436	731.065	9.5089
27	1.3308	96.98	.03476	16.4294	1197.341	.4291
28	.7610	59.65	.12178	12.3533	968.399	1.9769
28P	.7580	60.18	.12519	12.2254	970.664	2.0192
29	.5144	34.01	.44236	9.9298	656.489	8.5398
30	2.0803	20.16	.00873	103.4955	1003.216	.4341
31	.9612	15.74	.01255	57.5562	942.418	.7515
31P	.6533	14.60	.01556	39.3530	879.481	.9373
32	.3244	9.31	.02187	22.6867	651.391	1.5295
33	1.8068	159.32	.07396	13.5847	1197.932	.5561
34	1.1412	112.27	.24309	10.0987	993.540	2.1512
34P	1.0406	102.20	.28028	9.5464	937.587	2.5714
35	.7470	69.72	.88238	7.6619	715.032	9.0501

COMPUTED VALUES

RUN NO.	LB/BHP HR			LB/MODE		
	THC	CO	NOx	THC	CO	NOx
1	.011264	.924	.000566	.1014	8.312	.00510
1P	.010803	.928	.000555	.0989	8.494	.00508
2	.008407	.632	.001824	.0752	5.654	.01633
2P	.008480	.626	.001916	.0771	5.693	.01741
3	.006357	.390	.008042	.0584	3.579	.07387
3P	.006455	.409	.007632	.0591	3.738	.06982
4	.088641	1.437	.000041	.2549	4.133	.00012
				.0850	1.378	.00004
4P	.096611	1.433	.000020	.2784	4.130	.00006
				.0928	1.377	.00002
5	.033001	1.044	.000803	.0989	3.129	.00241
				.0330	1.043	.00080
5P	.033521	1.067	.000849	.0963	3.067	.00244
				.0321	1.022	.00081
6	.020556	.511	.001500	.0589	1.465	.00430
				.0196	.488	.00143
6P	.018882	.462	.001434	.0578	1.414	.00439
				.0193	.471	.00146
7	.009439	.832	.000593	.1347	11.877	.00846
7P	.009612	.873	.000395	.1397	12.692	.00574
8	.005823	.596	.001827	.0852	8.717	.02674
8P	.005785	.593	.001693	.0860	8.820	.02517
9	.004203	.367	.006361	.0617	5.391	.09338
9P	.004184	.348	.007360	.0612	5.195	.10976
10	.009173	.644	.001942	.0847	5.949	.01794
11	.007928	.841	.000468	.0084	.895	.00050
11P	.008040	.862	.000187	.0084	.899	.00020
12	.005217	.613	.001285	.0057	.666	.00140
12P	.005594	.681	.000847	.0060	.725	.00090
13	.003569	.393	.005758	.0039	.424	.00622
13P	.004007	.459	.004659	.0041	.465	.00472
15	.008360	.582	.001828	.0772	5.379	.01689
16	.008291	.812	.000510	.0088	.865	.00054
17	.009363	1.182	.000587	.0286	3.607	.00179
				.0095	1.202	.00060
18	.013018	.913	.000622	.1175	8.239	.00562
19	.007895	.585	.001544	.0728	5.399	.01424
19P	.007817	.586	.001529	.0736	5.516	.01439
20	.005927	.344	.005640	.0547	3.175	.05208
21	.096337	1.285	.000543	.2762	3.685	.00156
				.0921	1.228	.00052
22	.037521	.879	.001018	.1076	2.519	.00292
				.0359	.840	.00097
23	.022580	.619	.001359	.0691	1.893	.00416
				.0230	.631	.00139
24	.009993	.853	.000431	.1473	12.578	.00635
25	.006105	.584	.001361	.0938	8.977	.02091
25P	.006024	.619	.001174	.0913	9.382	.01780
26	.004009	.374	.004860	.0608	5.666	.07369
27	.014358	1.046	.000375	.1331	9.698	.00348
28	.008409	.659	.001346	.0761	5.965	.01218
28P	.008359	.664	.001381	.0758	6.018	.01252
29	.005702	.377	.004904	.0514	3.401	.04424
30	.144949	1.405	.000608	.4161	4.033	.00175
				.1337	1.344	.00058
31	.066775	1.093	.000872	.1922	3.148	.00251
				.0641	1.049	.00084
31P	.042588	.952	.001014	.1307	2.920	.00311
				.0436	.973	.00104
32	.021298	.612	.001436	.0649	1.863	.00437
				.0216	.621	.00146
33	.010328	.911	.000423	.1506	13.277	.00616
34	.006191	.609	.001319	.0951	9.356	.02026
34P	.005636	.554	.001518	.0867	8.516	.02336
35	.004000	.373	.004725	.0623	5.810	.07353

APPENDIX C2

IGNITION TIMING RECHECK RUNS

IO540 ENGINE TEST DATA

TEST CONDITION I.T. Recheck
IGNITION TIMING Var. °BTDC
ENGINE HOURS —
FUEL 100/130 LEADED

DATE 2/1/73
REL. HUMIDITY 60 %/ %
BARO. PRESSURE 29.35 IN HG.

RUN Nº	TIME	NOMINAL		OBSERVED		M.A.P	INDUCTION AIR		CRANK CASE	EXH.	FUEL	OBS.	OIL	
		RPM / A/F	IGN. TIMING	RPM	TORQUE FT. LBS	MM HG	FLOW CFM	TEMP. °F	FLOW CFM / TEMP °F	BACK. PRESS. PSI	FLOW PPH	F/A	TEMP °F	PRESS PSI
1	–	1900 / 11.5	25	1905	245		146.9	76	– / –		55.8			
2	–		20	1800	255		157.9	77	– / –		59.4			
3	–		15	1902	255		162.1	75	– / –		61.9			
4	–	1000 / 10.0	25	1007	80		40.2	74	– / –		17.7			
5	–		20	1004	80		41.7	74	– / –		18.0			
6			15	1002	80		44.8	71			19.2			
7		1000 / 11.5	25	1006	80		38.5	74			14.45			
8			20	1004	80		39.4	71			15.1			
9			15	[illegible]	80		41.2	71			15.8			
10		1000 / 13.0	25	1007	85		40.6	73			13.45			
11			20	1003	80		40.7	71			13.6			
12			15	1003	85		44.2	71			14.9			

TEST CONDITION I. T. RECHECK DATE 2/1/73

IGNITION TIMING VAR. °BTDC

ENGINE HOURS ― ― ― ― ― ― ―

RUN NO.	CYLINDER HEAD/EXHAUST PORT TEMP. °F						EXH. GAS TEMP. °F	EMISSIONS				
	#1	#2	#3	#4	#5	#6		THC PPM	CO %	CO_2 %	O_2 %	NOX PPM
1	/	/	/	/	/	/		870	9.1	8.6	195	1.25
2	/	/	/	/	/	/		860	9.0	8.6	165	1.00
3	/	/	/	/	/	/		810	9.0	8.6	135	1.00
4	/	/	/	/	/	/		5500	11.15	6.9	27	1.25
5	/	/	/	/	/	/		4600	10.1	7.6	38	1.10
6	/	/	/	/	/	/		4100	10.1	7.6	42	1.10
7	/	/	/	/	/	/		1710	7.1	9.7	71	1.20
8	/	/	/	/	/	/		2130	8.0	9.0	58	1.05
9	/	/	/	/	/	/		1530	7.3	9.7	65	1.00
10	/	/	/	/	/	/		1330	4.2	11.3	115	1.70
11	/	/	/	/	/	/		1300	4.1	11.4	108	1.10
12	/	/	/	/	/	/		1070	4.6	11.3	100	1.10

COMPUTED VALUES

RUN NO.	RPM	AIR-FUEL RATIO			CORRECTED CONCENTRATIONS				
		NOM.	DIRECT	C.B.	THC PPM-C	CO%	NOx PPM	CO2%	O2%
0 1	1900	11.5	11.4	11.7	2806	9.78	215.2	9.25	1.34
0 2	1900	11.5	11.5	11.6	2785	9.72	186.0	9.28	1.08
0 3	1900	11.5	11.4	11.6	2626	9.73	148.3	9.29	1.08
0 4	1000	10.0	9.9	10.0	16844	11.38	27.6	7.04	1.28
0 5	1000	10.0	10.1	10.5	14183	10.38	39.2	7.81	1.13
0 6	1000	10.0	10.3	10.6	12778	10.49	42.2	7.90	1.14
0 7	1000	11.5	11.7	12.3	5344	7.44	74.6	10.17	1.26
0 8	1000	11.5	11.5	11.7	6755	8.46	59.3	9.52	1.11
0 9	1000	11.5	11.5	12.1	4793	7.62	65.7	10.13	1.04
1 0	1000	13.5	13.3	13.5	4169	4.39	118.9	11.81	1.25
1 1	1000	13.0	13.2	13.5	4063	4.27	108.9	11.88	1.[illegible]
1 2	1000	13.0	13.1	13.3	3325	4.76	100.2	11.71	1.14
1 7	1000	10.0	10.1	10.2	16366	11.23	34.0	7.17	[illegible].39

RUN NO.	LB/HR			LB/1000 LB FUEL		
	THC	CO	NOx	THC	CO	NO x
0 1	.755842	53.219	.192265	13.5456	953.739	3.44562
0 2	.800027	56.359	.177191	13.4685	948.797	2.98301
0 3	.779251	58.284	.145916	12.5889	941.575	2.35729
0 4	1.324728	18.078	.007210	74.8434	1021.354	.40734
0 5	1.148833	16.930	.010522	63.8240	943.319	.58454
0 6	1.110585	18.416	.012171	57.8430	959.177	.63393
0 7	.389135	10.940	.018018	26.9298	757.099	1.24695
0 8	.504390	12.752	.014694	33.4033	844.5[illegible]	.97311
0 9	.378879	12.169	.017221	23.9797	770.168	1.08991
1 0	.317924	6.758	.030080	23.6374	502.468	2.23645
1 1	.312672	6.659	.027879	23.0641	489.653	2.04994
1 2	.280681	8.123	.028064	18.8377	545.144	1.88351
1 7	1.307928	18.126	.009005	70.6988	979.810	.48677

RUN NO.	LB/BHP-HR			LB/MODE		
	THC	CO	NOx	THC	CO	NOx
0 1	.008505	.599	.002164	.0756	5.322	.01923
0 2	.008672	.611	.001921	.0820	5.636	.01772
0 3	.008438	.631	.001580	.0779	5.828	.01459
0 4	.086364	1.179	.000470	.2649 .0883	3.616 1.205	.00144 .00048
0 5	.075120	1.110	.000688	.2298 .0766	3.396 1.132	.00210 .00070
0 6	.072764	1.207	.000797	.2221 .0740	3.683 1.228	.00243 .00081
0 7	.025394	.714	.001176	.0778 .0259	2.188 .729	.00360 .00120
0 8	.032981	.834	.000961	.1009 .0336	2.550 .850	.00294 .00098
0 9	.024849	.798	.001129	.0758 .0253	2.434 .811	.00344 .00115
1 0	.019507	.415	.001846	.0636 .0212	1.352 .451	.00602 .00201
1 1	.020531	.436	.001825	.0627 .0209	1.332 .444	.00558 .00186
1 2	.017291	.500	.001729	.0561 .0187	1.625 .542	.00561 .00187
1 7	.085694	1.188	.000590	.2616 .0872	3.625 1.208	.00180 .00060